Upright position mechanical ventilation: An alternative strategy for ALI/ARDS patients?

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Summary

Use of body positioning to improve oxygenation in mechanically ventilated patients with acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) has been well documented. However, neither prone position ventilation nor side lying ventilation has been reported to improve the survival. Whether there is a body position superior to routine supine position or other positions as therapeutic adjunct for ventilated patients with ALI and ARDS? We propose the hypothesis that upright position ventilation may be helpful to improve oxygenation and benefit patients with ALI/ARDS. According to the existing physiologic and pathophysiologic data of upright position investigation, we suppose that improvement of V/Q matching, increased functional residual capacity, alveolar recruitment, accelerated diaphragm recovery, early gastric emptying and enteric feeding may be a potential protect mechanism of upright position ventilation. Whether this can be translated into improvement in patient outcome should be further tested in clinical trial.

Introduction

Mechanical ventilation is the most common intervention to support patients with acute lung injury (ALI) and hypoxemic respiratory failure. For convenience of medical and nursing treatments, almost all ventilated patients are managed in the supine position. Changes in body position may alter the mechanics of the neural and respiratory system and, as a result, modify the mechanical load that the respiratory and abdominal muscles face to achieve an adequate alveolar ventilation [1,2]. In healthy subjects, a change in posture from supine to prone is associated with an increase in total pulmonary perfusion and an improvement in the distribution of density-normalized perfusion. Therefore, prone position ventilation (PPV) has been suggested since 1974 as an alternative method used in the treatment of ALI and acute respiratory distress syndrome (ARDS). Many mechanisms have been proposed to explain the beneficial effects of PPV. Improvement of ventilation/perfusion (V/Q) matching, decreased shunt flow, alveolar recruitment [3], affecting gravitational distribution of blood flow and decreased lung compression by the heart [4] all have been suggested. However, a recent systematic review and meta-analysis [5], including 1486 qualified patients, suggests that PPV does not improve survival for patients with acute hypoxemic respiratory failure, including ALI and ARDS, despite improved oxygenation and a reduced risk of ventilator-associated pneumonia.

The side lying positioning is also used frequently for adult mechanically ventilated patients in clinical setting. Improvement in the V/Q ratio [6], increased alveolar ventilation, and facilitated removal of bronchial secretions [7] has been suggested to be the main mechanism for improvement in oxygenation with side lying. However, associated with certain haemodynamic risks, especially in patients with moderate right ventricular dysfunction, side lying is only recommended for improving oxygenation in acute respiratory failure patients with unilateral lung involvement. The question therefore remains whether there is a body position superior to routine supine position or other positions as therapeutic adjunct for ventilated patients with ALI and ARDS?

Hypothesis

There are many factors which can influence ventilation and perfusion such as the branching structure of the airways, chest wall integrity, pleural pressure and even the body position. Humans have evolved to walk upright for several million years. The self-regulation mechanism of human lung is very exquisite. In the normal upright lung, the V/Q ratio is relatively high at the apex and low at its base due to the gradient in Q is steeper than that for V. Although regional ventilation and perfusion are heterogeneous, they are closely correlated with each other, ensuring efficient gas exchange. To date, although there is no direct evidence to support the upright position for improving oxygenation in ventilated patients with ALI/ARDS, the benefits of the upright position are widely investigated in spontaneously breathing and healthy
subjects. Accordingly, we propose the hypothesis that upright position ventilation may be helpful to improve oxygenation in patients with ALI/ARDS.

**Potential protection mechanisms of upright position ventilation**

Body position is known to have a direct effect on functional residual capacity (FRC) [8]. In the upright position, FRC and tidal volume (VT) increase both in healthy spontaneously breathing and anaesthetised subjects [9,10], due to lowering of the diaphragm and alveolar expansion. Interestingly, two "key ages" at which age and body position can interact to produce airway closure have been identified. The distribution of ventilation to the dependent lung was significantly affected and resulted in impairment of gas exchange in the supine healthy individual over 44 and in the upright individual over 65 years of age [11]. Obviously, this would have made the effects more marked in ventilated patients. In this sense, upright position is more favorable than supine to improve oxygenation.

For a supine patient with ALI/ARDS, perhaps only 20–30% of alveoli remain open, while the others are atelectatic by lung edema. The homogeneously distributed lung edema increases the hydrostatic pressure gradient down the lung, creating severe disturbances in ventilation and perfusion [12,13]. When switching from the supine to upright position, hydrostatic pressure gradient of lung, especially in dorsal sectors, may become relatively homogenous due to decreased lung compression by the heart, resulting in better V/Q matching and improved oxygen. Moreover, redistribution of lung perfusion by gravity increased the number of well-perfused lung units, which added the possibility of lung recruitment.

Pulmonary edema is a serious complication associated with ALI/ARDS, especially in post-pneumonectomy patients [14]. While in the supine position, about one quarter of the human body's blood volume is in the thorax [15]. The increased postoperative blood flow through the remaining lung promotes disruption of the capillary endothelial cell–alveolar barrier, allowing protein-rich fluid to flood the alveolus [16]. The noncardiac edema is predominantly located in the peripheral tissues that surround large vessels rather than in lung bases and periphery. The diminished venous return that occurs with upright posture may result in ameliorated lung edema.

Prolonged mechanical ventilation has been demonstrated to usually result in diaphragmatic contractile dysfunction due to the disuse atrophy of the diaphragm [17,18]. In humans, the most deformable part of the chest wall is its diaphragmatic boundary, and hence a greater potential for distortion exists in horizontal postures because of the abdominal pressure gradient. When ventilated patients were managed in the horizontal position including supine and prone position, abdominal contents pushed the diaphragm in a cephalad direction and placed the dysfuntioned diaphragm at an unfavorable position on its length–tension curve. In the upright position, however, gravitational forces pulled the abdominal contents down and outward along with the diaphragm, which made the diaphragm at a more favorable point on the length–tension relationship [19]. It is well established that standing in humans from a supine position could produce diaphragm shortening in order to maintain stable ventilation [20]. Therefore, upright posture may keep the diaphragm more favorable tonic activity and compliant and, as a result, accelerate diaphragm recovery from disuse atrophy.

Reduced gastrointestinal tract motility is common in critically ill patients. Medications such as dopamine and sedation [21], hyperglycemia [22] or increased intracranial pressure [23] have all been shown to depress the gut activity. Accordingly, the incidence of delayed gastric emptying and gastric contents aspiration is high in ventilated patients. The supine position seems to be an important risk factor in causing the aspiration of gastric contents [24]. Pneumatikos et al. showed that aspiration in mechanically ventilated patients occurs even when they are kept in a semirecumbent position [25]. Enteral feeding preserves gut mucosal integrity which may act as a barrier against the endogenous bacteria implicated in the pathogenesis of nosocomial pneumonia, sepsis and multiple organ failure. Unfortunately, the application of enteral nutrition via the nasogastric tube is restricted due to delayed gastric emptying. It is, however, conceivable that the subsequent change of position from supine to upright may have a clinical benefit with accelerating gastric emptying and minimizing the risk of aspiration pneumonia in patients with enteral feeding.

**Clinical implications**

In clinical practice, the upright or high sitting position is usually the first choice for optimization of oxygenation and gas exchange. According to our analysis presented above, upright positioning may be considered as a rescue therapy for ALI/ARDS ventilated patients except for unstable spinal cord injuries, hemodynamic instability, inability to tolerate upright position and high probability of death during the following 24 h in the ICU. Upright position may be poorly tolerated in the asthenic patients. Therefore, a suitable device should be designed for stabilizing the patients comfortably to minimize any potential hazard. It is regarded as effective when there is an increase in PaO2/FiO2 > 10 compared with the baseline value before upright position, in concordance with the criterion used in prone position test [26]. The time which a patient spends for upright position ventilation is based on the outcome of posture change. In conclusion, the upright position ventilation may be beneficial for ALI/ARDS ventilated patients resulting from improvement of V/Q matching, increased FRC, alveolar recruitment, accelerated diaphragm recovery, early gastric emptying and enteral feeding. Whether this can be translated into improvement in patient outcome has yet to be tested in clinical trials.

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**References**


