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Seated and semi-recumbent positioning of the ventilated intensive care patient – Effect on gas exchange, respiratory mechanics and hemodynamics

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ABSTRACT

Objectives: To compare the effect of semi-recumbent and sitting positions on gas exchange, respiratory mechanics and hemodynamics in patients weaning from mechanical ventilation.
Background: Upright positions are encouraged during rehabilitation of the critically ill but there effects have not been well described.
Methods: A prospective, randomized, cross-over trial was conducted. Subjects were passively mobilized from supine into a seated position (out of bed) and from supine to a semi-recumbent position (>45° backrest elevation in bed). Arterial blood gas (PaO_2/FiO_2, PaO_2, SaO_2, $PaCO_2$ and A–a gradient), respiratory mechanics (V_E, V_T, RR, C_{dyn}, RR/V_T) and hemodynamic measurements (HR, MABP) were collected in supine and at 5 min and 30 min after re-positioning.
Results: Thirty-four intubated and ventilated subjects were enrolled. The angle of backrest inclination in sitting (67 ± 5°) was greater than gained with semi-recumbent positioning (50 ± 5°, $p < 0.001$). There were no clinically important changes in arterial blood gas, respiratory mechanic or hemodynamic values due to either position.
Conclusions: Neither position resulted in significant changes in respiratory and hemodynamic parameters. Both positions can be applied safely in patients being weaned from ventilation.

Introduction

The practice of early mobilization of the intensive care patient is considered to be safe[1,2] and appears to positively influence intensive care outcomes. For example, a focus on early mobilization can improve the functional ability of patients during the intensive care period[3,4] and at hospital discharge.[1] Additionally, it may increase ventilator-free days[1] and reduce intensive care and hospital length of stay.[5] As part of these early mobilization strategies, the positioning of patients upright in bed or out of bed is encouraged in order to overcome possible respiratory and/or cardiovascular complications of immobility.[1] Positioning patients semi-recumbent up to 60° is usually well tolerated hemodynamically, with minimal impact on cardiac output[6,7] and 45° semi-recumbent positioning has been shown to significantly reduce the incidence of ventilator-associated pneumonia.[8] Outside of the intensive care unit, research involving subjects from both normal and diseased populations have shown significant improvement in pulmonary function associated with movement from a supine to an erect semi-recumbent (in bed)

Abbreviations: A–a gradient, alveolar gas to arterial blood oxygen tension difference; ALI, acute lung injury; APACHE, acute physiological and chronic health evaluation II score; BMI, body mass index; C_{dyn}, dynamic lung compliance; CV, closing volume; FiO_2, fraction of inspired oxygen; FRC, functional residual capacity; HR, heart rate; MABP, mean arterial blood pressure; MLI, Murray lung injury; P, linear mixed model main effect analysis for position (sitting or semi-recumbent); $P \times T$, linear mixed model analysis for position and time interaction; $PaCO_2$, partial pressure of carbon dioxide in arterial blood; PaO_2, partial pressure of oxygen in arterial blood; PIP_{aw}, peak inspiratory airway pressure; RR, respiratory rate; RR/V_T, shallow breathing index; SaO_2, arterial hemoglobin oxygen saturation; SOFA, sepsis-related organ failure assessment; SpO_2, pulse oximeter oxygen saturation; T, liner mixed model main effect analysis for time; T0, time of measurement, baseline starting position; T5, time of measurement, 5 min post intervention; T30, time of measurement, 30 min post intervention; V_E, minute ventilation; V_T, tidal volume.

Conflicts of interest: All authors have none to declare.

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or seated position (out of bed).[9–14] These benefits include increases in functional residual capacity (FRC),[10–12] lung compliance[14,15] and adoption of large tidal volume-low respiratory rate patterns of breathing.[14] In some people, the changes in lung volume and mechanics on moving from a supine to seated position may result in improvement in the partial pressure of oxygen in arterial blood (PaO_2) and other indices of gas exchange.[10,11]

Knowledge of the influence of position on gas exchange and/or respiratory mechanics is important during weaning from mechanical ventilation. If adoption of a seated or semi-recumbent position results in improved gas exchange, lung compliance and/or tidal volume and a reduction in respiratory rate and work of breathing, their utilization may prevent respiratory muscle fatigue and shorten the weaning process. Additionally, there could be advantages in moving a patient out of bed and into a seated position. Investigation in normal subjects suggests that positioning a patient into a seated posture may result in greater improvements in FRC than are gained with a semi-recumbent position.[13] Maintaining a patient in a semi-recumbent position can be challenging in clinical practice[16–18] and if patients slide out of a semi-recumbent position into a slumped position it may further reduce lung volume.[13]

Several studies have examined the effect of a semi-recumbent or seated position on gas exchange and/or respiratory mechanics in specific intensive care populations including patients with acute lung injury,[19–22] abdominal distension[23] and post-operative abdominal surgery.[24,25] However, only two studies have recruited patients specifically during the stages of weaning from mechanical ventilation.[26,27] These two studies report no significant deleterious effects of sitting or semi-recumbent positions. However, respiratory effort may be higher in sitting[26]; and sitting may result in smaller improvements in inspiratory muscle strength.[27] Neither study has reported the effect on arterial blood gas measurements. Changes in compliance may account for increased respiratory effort,[26] and have previously been hypothesized to impact on changes in oxygenation indices.[20,22]

The aim of this study was to compare the effects of sitting out of bed and semi-recumbent positioning in bed when applied in ventilated (>48 h) intensive care patients. The null hypothesis was that a change in position from supine to either a seated or semi-recumbent position would not affect gas exchange, respiratory mechanics, or hemodynamic values.

Methods

A prospective, randomized, cross-over trial design was used with concealed allocation to the first position examined.

Ethical approval for this study was gained from the relevant institutional human research ethics committee. Written informed consent to participation was gained from participants and/or their authorized legal guardian. Participants were recruited from the intensive care unit of a tertiary-referral, university-affiliated, metropolitan centre. Patients receiving mechanical ventilation for more than 48 h were screened and consent for participation sought if there were no absolute contraindications to sitting and their cardiovascular and respiratory parameters were stable according to the criteria outlined in Table 1.

As there was limited published data investigating the effect of upright positioning on arterial blood gas measurements and respiratory mechanics in patients weaning from mechanical ventilation, an interim analysis was conducted after enrollment of 20 patients and was used to estimate the standard deviation for paired differences in PaO_2/FiO_2 and V_E from supine to sitting and semi-recumbent positioning. A sample size estimate of 34 patients was calculated to detect moderate effect sizes and clinically significant changes in PaO_2/FiO_2 (difference = 20, σ = 35, α = 0.05, power = 0.9) and V_E (sample estimate = 27, difference = 1 L/min, σ = 1.55 L/min, α = 0.05, power = 0.9) in a repeated measures design.[28]

Admission diagnosis, demographic information, sepsis-related organ failure assessment (SOFA) scores[29] and Murray lung injury (MLI) scores[30] were calculated from data collected on the day of the study. Automated calculations for acute physiological and chronic health evaluation II (APACHE) scores[31] were obtained from the intensive care unit's clinical information system.

Ventilator settings and respiratory mechanics (respiratory rate (RR), tidal volume (V_T), minute ventilation (V_E), peak inspiratory airway pressure (PIP_{aw}), dynamic lung compliance (C_{dyn}) were recorded via electronic transfer of data from the serial port of the ventilator (Mallinckrodt Puritan Bennet 7200® or 840™ ventilator), which were calibrated according to manufacturer's recommendations. A shallow breathing index was also calculated as RR/V_T. Ventilator measurement of pressure, volume and flow are considered to be accurate and have low variability.[32,33] However, at each data collection point, 5-min periods of respiratory mechanic measurements were collected and averaged to reduce any breath-to-breath variability of measurements.[34,35]

Variations in gas exchange were monitored through arterial blood gas sampling (ABL 700 Series machines – Radiometer, Copenhagen, Denmark) and analysis of the ratio of PaO_2 to FiO_2 (PaO_2/FiO_2), PaO_2, the partial pressure of carbon dioxide in arterial blood ($PaCO_2$), arterial hemoglobin oxygen saturation (SaO_2), and alveolar gas to arterial blood oxygen tension difference (A–a gradient).

Heart rate (HR), MABP and SpO_2 were recorded from the patient monitoring system (Philips Intellivue). For MABP measurements, arterial blood pressures were manually checked for accuracy/calibration against sphygmomanometer readings prior to data collection and the arterial line transducer placement was re-zeroed prior to each recording.

Table 1
Study inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Age >18 years	Signs of new or sustained sepsis on the day of enrollment
Intubated and receiving mechanical ventilation (>48 h)	Hemoglobin <70 g/L
Suitable candidates to mobilize into either the seated or semi-recumbent position.	Platelets $<30 \times 10^9$/L
To ascertain this, clinical characteristics had to include:	
PaO_2 >60 mm Hg	Vasopressor or neuromuscular blockade medications
FiO_2 <0.6	Nitric oxide
PIP_{aw} <40 cm H_2O	Pulmonary barotrauma (e.g. flail chest, untreated pneumothorax)
Stable hemodynamic parameters	Burn injuries
HR 60–130 beats/min	Dialysis
MABP 70–120 mm Hg	Contraindications to upright positioning (e.g. unstable spinal column fractures or spinal cord injury)
Arrhythmias (if present) stable and not compromising blood pressure	Intracranial pressure monitoring