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Respiration and the Airway

RESPIRATION AND THE AIRWAY

Increasing positive end-expiratory pressure (re-) improves intraoperative respiratory mechanics and lung ventilation after prone positioning

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Abstract

Background: Turning a patient prone, changes the respiratory mechanics and potentially the level of positive end-expiratory pressure (PEEP) that is necessary to prevent alveolar collapse. In this prospective clinical study we examined the impact of PEEP on the intratidal respiratory mechanics and regional lung aeration in the prone position. We hypothesized that a higher PEEP is required to maintain compliance and regional ventilation in the prone position.

Methods: After ethical approval, 45 patients with healthy lungs undergoing lumbar spine surgery were examined in the supine position at PEEP 6 cm H_2O and in the prone position at PEEP (6, 9 and 12 cm H_2O). Dynamic compliance (C_{RS}) and intratidal compliance-volume curves were determined and regional ventilation was measured using electrical impedance tomography. The compliance-volume curves were classified to indicate intratidal derecruitment, overdistension, or neither.

Results: C_{RS} did not differ between postures and PEEP levels (P>0.28). At a PEEP of 6 cm H_2O a compliance-volume profile indicating neither derecruitment nor overdistension was observed in 38 supine, but only in 20 prone positioned patients (P<0.001). The latter increased to 33 and 37 (both P<0.001) when increasing PEEP to 9 and 12 cm H_2O, respectively. Increasing PEEP from 6 to 9 cm H_2O in the prone position increased peripheral ventilation significantly.

Conclusions: Respiratory system mechanics change substantially between supine and prone posture, which is not demonstrated in routine measurements. The intratidal compliance analysis suggests that in most patients a PEEP above commonly used settings is necessary to avoid alveolar collapse in the prone position.

Clinical trial registration: DRKS 00005692.

Key words: circulatory and respiratory physiological phenomena; lung-compliance; lung; positive-pressure respiration; posture; prone position; respiration, artificial; respiration; respiratory mechanics

Mechanical ventilation during anaesthesia promotes alveolar collapse, even in patients with healthy lungs.[1] PEEP is applied in order to prevent alveolar collapse, avoiding the stress and strain at alveolar units that is caused by cyclic derecruitment and recruitment, a phenomenon known to result in atelectrauma.[2] However, the optimal level of PEEP is still not known in healthy

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Editor's key points

- There are few data on optimum PEEP during anaesthesia in the prone position.
- In this study, prone positioning had no effect on dynamic respiratory compliance but gas distribution was greater in non-dependent regions.
- PEEP of 6 cm H_20 was adequate for almost all patients when supine, but a PEEP of 9 cm H_20 or greater was required to minimize cyclical alveolar collapse in the prone position.
- Higher than usual PEEP settings may be required when patients are positioned prone.

patients. Recently, ventilation with optimal PEEP and recruitment manoeuvres (i.e. perioperative lung protective ventilation), has been associated with fewer postoperative pulmonary complications[3–5] and lower mortality.[6] While published studies focus on patients in the supine position, little is known about the effects on the lung during ventilation in the prone position, and surgery in the prone position is increasing as the global incidence of spine disorders increases.[7] Positioning of anaesthetized, lung healthy patients from supine to prone increases functional residual capacity (FRC) and arterial oxygenation (paO_2).[8 9] Additionally, it also effects regional ventilation and thus ventilation homogeneity as the gravitational forces act conversely, compared with supine.[10] Based on the modified physiological conditions, patients turned in the prone position might require adjustment of PEEP to avoid intratidal derecruitment.

This study investigates the mechanics of the respiratory system of lungs in healthy patients in the supine position and in three different PEEP levels in the prone position. In addition to respiratory system compliance, the course of the intratidal compliance-volume curves were analysed and classified.[11] An improved respiratory mechanical situation was defined as the presence of a horizontal compliance-volume profile, as this indicates neither tidal derecruitment nor end-tidal overdistension. In order to measure regional lung ventilation we used electrical impedance tomography (EIT), which is a radiation free, real-time imaging technique for displaying the regional ventilation within a cross-sectional plane in the lungs.[12]

We hypothesized that during mechanical ventilation in the prone position (a) the routinely applied PEEP level is too low to protect against intratidal derecruitment and that (b) a moderate increase in PEEP would improve compliance and regional lung ventilation.

Methods

In this prospective cross-over clinical study we included adult patients undergoing elective minimally invasive surgery of the lumbar spine. All patients underwent spirometry (Vitalograph In2itive, Hamburg, Germany) in a sitting position the day before surgery. Patients were included if the fraction of forced expiratory value in 1 s (FEV_1) was higher than 0.8 of the predicted value and the fraction of the ratio of FEV_1 and forced vital capacity (FVC), FEV_1 /FVC, was higher than 0.7.[13] Criteria for exclusion were age <18 yr, pregnancy, obesity (BMI>35), acute or chronic pulmonary disease (requiring bronchodilator medication) and any contraindication to the use of EIT (i.e. implanted electrical device). The study was approved by the ethics committee of the University Medical Center Freiburg (EK 14/14) and pre-registered at the German Register for Clinical Trials (DRKS 00005692). Written informed consent was obtained from all patients before intervention.

Anaesthesia

To perform EIT measurements, an electrode belt with an array of 16 electrodes was placed around the thorax, at the fifth intercostal space. After establishing standard monitoring, anaesthesia was induced with sufentanil (0.5 μg kg^{-1}) and target-controlled infusion (TCI) of propofol (3–4 μg ml^{-1}; Schnider model). Rocuronium (0.4–0.6 mg kg^{-1}) was used for muscle relaxation. Neuromuscular monitoring was performed using mechanomyography (Stimpod NMS450, Xavant Technology Ltd, South Africa). Sufficient conditions for intubation were presumed at a train-of-four ratio less than 0.25.[14] After face mask ventilation the patient was intubated with a high-volume, low-pressure cuffed tracheal tube (Mallinckrodt™, Dublin, Ireland). Intratracheal placement of the tracheal tube was confirmed by bilateral auscultation and end-expiratory CO_2 measurement. The tracheal tube's cuff pressure was kept within a range of 20 to 25 cm H_2O. Anaesthesia was maintained as total i.v. anaesthesia by continuing TCI of propofol (2–3 μg ml^{-1}) and continuous infusion of remifentanil (0.1–0.2 μg kg^{-1} min^{-1}). Hypotension (mean arterial pressure <60 mm Hg) was treated with continuous infusion of norepinephrine (0.02–0.1 μg kg^{-1} min^{-1}).

Study protocol

During the measurements patients' lungs were ventilated in the volume controlled mode (Zeus, Dräger, Lübeck, Germany) with a tidal volume (V_t) of 6–8 ml kg^{-1}. Normal body weight was calculated using Broca's index (normal weight=height [cm] – 100).[15] The end-inspiratory plateau-pause was 20% and the fraction of inspired

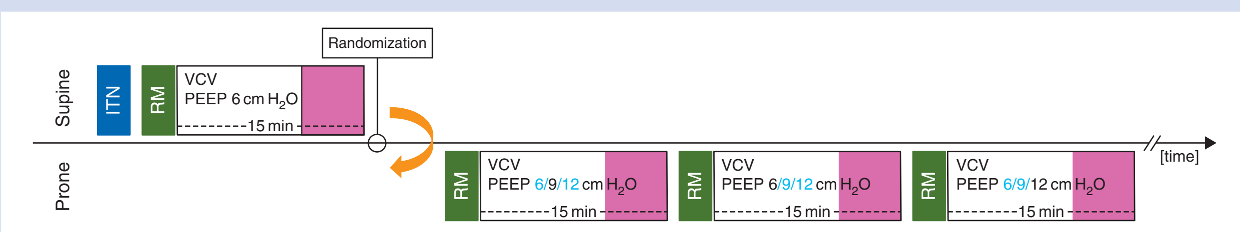

Fig 1 Study protocol. After induction of anaesthesia (ITN) all patients received measurements in the supine position at a positive end-expiratory pressure (PEEP) of 6 cm H_2O. After prone positioning, three different PEEP levels were applied in random order. Each PEEP interval was preceded by a lung recruitment manoeuvre (RM) and maintained for at least 15 min to allow for equilibration of the respiratory system. EIT and respiratory measurements were performed in the last five min of each PEEP interval (pink-shaded areas). VCV: volume controlled ventilation (tidal volume=6–8 ml kg^{-1} normal body weight). Please note that interventions started directly after induction of anaesthesia and were carried out in immediate succession.