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Clinical Investigation

CLINICAL INVESTIGATION

Individualized positive end-expiratory pressure in obese patients during general anaesthesia: a randomized controlled clinical trial using electrical impedance tomography

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Abstract

Background. General anaesthesia leads to atelectasis, reduced end-expiratory lung volume (EELV), and diminished arterial oxygenation in obese patients. We hypothesized that a combination of a recruitment manoeuvre (RM) and individualized positive end-expiratory pressure (PEEP) can avoid these effects.

Methods. Patients with a BMI $\geq$35 kg m^{-2} undergoing elective laparoscopic surgery were randomly allocated to mechanical ventilation with a tidal volume of 8 ml kg^{-1} predicted body weight and (i) an RM followed by individualized PEEP titrated using electrical impedance tomography ($PEEP_{IND}$) or (ii) no RM and PEEP of 5 cm H_2O ($PEEP_5$). Gas exchange, regional ventilation distribution, and EELV (multiple breath nitrogen washout method) were determined before, during, and after anaesthesia. The primary end point was the ratio of arterial partial pressure of oxygen to inspiratory oxygen fraction (PaO_2/FiO_2).

Results. For $PEEP_{IND}$ (n=25) and $PEEP_5$ (n=25) arms together, PaO_2/FiO_2 and EELV decreased by 15 kPa [95% confidence interval (CI) 11–20 kPa, P<0.001] and 1.2 litres (95% CI 0.9–1.6 litres, P<0.001), respectively, after intubation. Mean (SD) $PEEP_{IND}$ was 18.5 (5.6) cm H_2O. In the $PEEP_{IND}$ arm, PaO_2/FiO_2 before extubation was 23 kPa higher (95% CI 16–29 kPa; P<0.001), EELV was 1.8 litres larger (95% CI 1.5–2.2 litres; P<0.001), driving pressure was 6.7 cm H_2O lower (95% CI 5.4–7.9 cm H_2O; P<0.001), and regional ventilation was more equally distributed than for $PEEP_5$. After extubation, however, these differences between the arms vanished.

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Conclusions. In obese patients, an RM and higher $PEEP_{IND}$ restored EELV, regional ventilation distribution, and oxygenation during anaesthesia, but these differences did not persist after extubation. Therefore, lung protection strategies should include the postoperative period.

Clinical trial registration. German clinical trials register DRKS00004199, www.who.int/ictrp/network/drks2/en/.

Key words: bariatric surgery; lung volume measurements; obesity, morbid; positive-pressure respiration; pulmonary gas exchange

Editor's key points

- The optimal level of PEEP varies widely, particularly in obese patients.
- This study examined the effect of a recruitment manoeuvre followed by titrated PEEP on gas exchange and lung volumes in obese patients undergoing laparoscopic surgery.
- In the intervention group, a mean PEEP value of 18 cm H_2O was required to optimize end-expiratory lung volume; this resulted in a significant improvement in gas exchange and regional ventilation, but the differences between groups disappeared after tracheal extubation.
- Patients receiving optimized PEEP had higher requirements for i.v. fluids and vasopressors.
- These data support the use of higher PEEP values in obese patients than are routinely practised, but further interventions may be needed to prevent postoperative atelectasis.

Induction of general anaesthesia causes atelectasis, decreased end-expiratory lung volume (EELV), and diminished arterial oxygenation,[1] especially in obese patients.[2] Atelectasis leads to tidal recruitment, hyperinflation of reduced functional lung volume, and may thus contribute to ventilation-induced lung injury (VILI) and pulmonary and non-pulmonary complications after surgery.[3]

Application of recruitment manoeuvres (RM) followed by sufficient PEEP can reopen collapsed lung regions[4] and prevent expiratory re-collapse.[25] The level of PEEP required depends on the patient's individual constitution, BMI, and positioning, and can therefore vary widely, especially in obese patients.[6] Given that individual opening and closing pressures cannot be determined in the operating room, many anaesthetists currently use a rather low standard PEEP.[7]

In this context, objective methods to individualize PEEP could play an important role. Among others, the regional ventilation delay index (RVDI) method[8 9] (see Supplementary mate rial), which is based on electrical impedance tomography (EIT) imaging, estimates the lowest PEEP that minimizes cyclic tidal recruitment and collapse,[9] which are believed to play a major role in VILI. Assuming that obese patients present increased pleural pressures, it is very likely that the combination of RM and PEEP individualized with RVDI will result in consistently higher PEEP than is currently used during anaesthesia (5 cm H_2O).[10]

Bearing this in mind, we conducted a randomized controlled trial on obese patients during anaesthesia for laparoscopic surgery and in the early postoperative period and hypothesized that an RM followed by individualized PEEP will persistently improve gas exchange, EELV, and regional ventilation distribution compared with the standard PEEP of 5 cm H_2O.

Methods

A detailed description of the methods and the study protocol are provided as Supplementary material.

Patients were recruited for this parallel arm, randomized controlled single-centre trial (German clinical trials register no. DRKS00004199, www.who.int/ictrp/network/drks2/en/; accessed 21 June 2017) at the University Hospital of Leipzig. Approval for the trial was granted by the Leipzig University Ethics Committee (no. 196-11-ff-8042011), and all patients gave written informed consent before inclusion.

Patients

Between November 2012 and July 2013 obese patients with a BMI $\geq$35 kg m^{-2}, age $\geq$18 yr, and with a medium or high risk of postoperative pulmonary complications [Assess Respiratory rIsk in Surgical patients in CATalonia (ARISCAT) score $\geq$26][11] undergoing elective laparoscopic surgery were randomized to either the standard PEEP of 5 cm H_2O ($PEEP_5$) or the individualized PEEP ($PEEP_{IND}$) arm.

Anaesthesia

All patients received infusion of crystalloid fluid at the discretion of the responsible anaesthetist not involved in the study, and total i.v. anaesthesia using propofol and remifentanil. Routine perioperative monitoring included invasive measurement of arterial blood pressure.

Constant-flow, volume-controlled mechanical ventilation was provided by an intensive care ventilator (EVITA-XL; Dräger Medical, Lübeck, Germany), with a tidal volume (V_T) of 8 ml kg^{-1} predicted body weight and inspiratory oxygen fraction (FiO2) of 0.4 or higher if necessary to reach peripheral capillary oxygen saturation (SpO_2) $\geq$92%. Inspiratory and expiratory times were set to achieve zero flow with inspiratory pause, and respiratory rate was set to 12 bpm. During anaesthesia, respiratory rate, inspiratory flow, and inspiratory-to-expiratory ratio were adjusted as required to maintain normocapnia [4.7$\leq$ arterial partial pressure of carbon dioxide (Pa_{CO_2}) $\leq$6.0 kPa].

Protocol

All patients were initially placed in the 20° head-elevated (ramped) position. Timing of measurements, ventilation and PEEP setting, and the positioning of patients are illustrated in Fig. 1. Before induction of anaesthesia and 2–6 h after extubation, EELV and EIT were measured in the spontaneously breathing patient using a mouthpiece and a nose clamp at ambient air