BJA

British Journal of Anaesthesia, 116 (1): 122–30 (2016)

doi: 10.1093/bja/aev398
Respiration and the Airway

Double-lumen tubes and auto-PEEP during one-lung ventilation

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Abstract

Background: Double-lumen tubes (DLT) are routinely used to enable one-lung-ventilation (OLV) during thoracic anaesthesia. The flow-dependent resistance of the DLT's bronchial limb may be high as a result of its narrow inner diameter and length, and thus potentially contribute to an unintended increase in positive end-expiratory pressure (auto-PEEP). We therefore studied the impact of adult sized DLTs on the dynamic auto-PEEP during OLV.
Methods: In this prospective clinical study, dynamic auto-PEEP was determined in 72 patients undergoing thoracic surgery, with right- and left-sided DLTs of various sizes. During OLV, air trapping was provoked by increasing inspiration to expiration ratio from 1:2 to 2:1 (five steps). Based on measured flow rate, airway pressure (P_{aw}) and bronchial pressure (P_{bronch}), the pressure gradient across the DLT (ΔP_{DLT}) and the total auto-PEEP in the respiratory system (i.e. the lungs, the DLT and the ventilator circuit) were determined. Subsequently the DLT's share in total auto-PEEP was calculated.
Results: ΔP_{DLT} was 2.3 (0.7) cm H_2O over the entire breathing cycle. At the shortest expiratory time the mean total auto-PEEP was 2.9 (1.5) cm H_2O (range 0–5.9 cm H_2O). The DLT caused 27 to 31% of the total auto-PEEP. Size and side of the DLT's bronchial limb did not impact auto-PEEP significantly.
Conclusions: Although the DLT contributes to the overall auto-PEEP, its contribution is small and independent of size and side of the DLT's bronchial limb. The choice of DLT does not influence the risk of auto-PEEP during OLV to a clinically relevant extent.
Clinical trial registration: DRKS00005648.

Key words: airway management; airway resistance; intrinsic peep; one-lung ventilation

Expiratory flow-dependent resistance during mechanical ventilation can lead to auto-PEEP and to progressive dynamic hyperinflation of the lungs.[1 2] Auto-PEEP develops when tidal volume cannot be evacuated during the allocated expiratory time. Three factors, sometimes in combination, predispose to auto-PEEP generation (1) respiratory mechanics of the patient (i.e. patients with chronic obstructive airways disease may more readily develop auto-PEEP), (2) ventilator settings with inappropriately short expiratory times and (3) the added resistance of the artificial airways, comprising ventilator tubing, heat and moisture exchanger and, during one-lung ventilation (OLV), the double-lumen tube (DLT).[3–5] While the influence of the patients' respiratory mechanics has already been the subject of multiple clinical trials,[2 6 7] the role of the ventilator settings and the DLTs' flow-dependent resistance has not been examined systematically. The DLT is the device of choice for establishing OLV during thoracic surgical procedures.[8] For

Accepted: September 15, 2015

Editor's key points

- The contribution of double lumen endobronchial tubes (DLT) on resistance to expiration during one-lung ventilation (OLV) is unknown.
- This clinical study evaluated the effect of DLT size and changing ventilation on gas flow rate and airway pressures.
- There was a consistent increase in airway pressure across the DLT, relatively unaffected by DLT size.
- These data suggest that using a DLT during OLV increases positive end-expiratory pressure (auto-PEEP) to a moderate extent.

that purpose the DLT combines a shorter tracheal and a longer bronchial limb for either right- or left-sided bronchial placement, respectively to the bronchial anatomy, by differing in curvature and existence of a 'Murphy-eye' for ventilation of the right upper lobe. Although a previous study has shown low resistance of the DLT during two-lung ventilation,[3] during OLV particularly the expiratory flow-dependent resistance of the DLT's bronchial lumen may increase the pressure gradient across the DLT, thus contributing to auto-PEEP.[4 6]

This prospective clinical study investigates to which extent the pressure gradient across the DLT (ΔP_{DLT}) contributes to auto-PEEP during OLV, depending on the DLT's size and side of bronchial limb. Therefore expiratory time was consecutively shortened during OLV, expecting increased probability of auto-PEEP.

We hypothesized that the DLT's contribution to auto-PEEP during OLV depends on the internal diameter and the side of the DLT's bronchial limb, and the expiratory time.

Methods

This prospective clinical study was performed in the Department of Anesthesiology and Intensive Care Medicine, University Medical Center Freiburg. Patients were enrolled from January to October 2014. The study was approved by the institutional review board (Research Ethics Committee) at the University Medical Center Freiburg and registered at the German Clinical Trials Register (DRKS 00005648) before enrolment of the first patient. Written informed consent was obtained from every patient included in this study. Inclusion criteria were age between 18 and 75 yr, ASAphysical status I-III, and lung resection via open thoracotomy or thoracoscopic procedure. Exclusion criteria were additional chest wall resection, emergency surgery, pregnancy, obesity (BMI>50 kg m^{-2}), terminal illness and any type of implanted automatic device (i.e. pacemaker). All patients received preoperative lung function testing.

Anaesthesia

After establishing standard monitoring, patients received regional anaesthesia (epidural anaesthesia, paravertebral block, intercostal block) if not contraindicated. Subsequently, anaesthesia was induced with sufentanil (0.4–0.6 μg kg^{-1}) and target-controlled infusion (TCI, Propofol 1% MCT Injectomat TIVA Agilia, Fresenius-Kabi GmbH, Bad Homburg, Germany) of propofol at plasma concentration of 2–4 μg ml^{-1}. Cisatracurium 0.1 mg kg^{-1} (Nimbex®, GlaxoSmithKline, Munich, Germany) was administered to facilitate tracheal intubation. Anaesthesia was maintained with propofol TCI at plasma concentrations of 2–4 μg ml^{-1} and additional bolus doses of sufentanil 0.1–0.2 μg ml^{-1}. The depth of anaesthesia was monitored by the bispectral index of the EEG (BIS, BISw A-2000 monitor, average time=30 s; Aspect Medical Systems, Newton, MA, USA) and the BIS value was kept between 40 and 60.

Double-lumen tubes selection

Patients were prospectively screened for tracheal intubation with a DLT of the Robertshaw type (Broncho-Cath™, Mallinckrodt, Dublin, Ireland) with right- or left-sided bronchial limb and 35, 37 or 39 Fr outer diameter (OD). At least 12 patients were recruited to each of 6 resultant study groups (DLT's side and OD). Left-sided DLTs were chosen for right-sided surgery, respectively right-sided DLT for left-sided surgery to ensure OLV across the bronchial limb. The appropriate size of the DLT was chosen by the attending anaesthetist, based on measurement of the inner bronchial diameter derived from either CT scan or chest X-ray,[9–11] following clinical routine. The correct position of the DLT was verified by flexible fibre optic bronchoscopy after tracheal intubation and after patient positioning for surgery.

Intraoperative ventilator settings

During two-lung ventilation, the lungs were ventilated in the pressure-controlled mode (Zeus, Dräger, Luebeck, Germany) at tidal volumes of 6–8 ml kg^{-1} and an inspired oxygen fraction ($F_{I_{O_2}}$) of 0.6. Respiratory rates were set to maintain end-tidal carbon dioxide partial pressure between 4.9 and 5.7 kPa. External PEEP was set individually for each patient at the discretion of the anaesthetist and was kept at a constant level in the period of measurements. During OLV, peak inspiratory pressure was adjusted to achieve tidal volumes at 6 ml kg^{-1} and $F_{I_{O_2}}$ was increased to 0.6–1.0. Respiratory rates were set to maintain end-tidal carbon dioxide concentration between 4.6 and 5.9 kPa with a maximum of 12 bpm using a routine inspiration to expiration (I:E) ratio of 1:2. The DLT's tracheal- and bronchial-cuff pressures were kept within a range of 20 to 25 cm H_2O. To enable OLV the tracheal limb of the DLT was disconnected from the ventilator and kept open to atmosphere (Fig. 1).

In order to increase the probability of auto-PEEP during OLV expiratory time was consecutively shortened by setting I:E ratio from 1:2 to 1:1.5, 1:1, 1.5:1 and 2:1. In between, the expiratory time was set back to baseline for 1 min, to avoid carry-over effects.

Intraoperative, flow and airway pressure measurements

Airway pressure (P_{aw}) and flow rate (V') were measured by means of a pneumotachograph (Fleisch Type 1, Dr. Fenyves & Gut, Hechingen, Germany). Tidal volume (V_t) was numerically integrated from V'.

In order to measure the bronchial pressure (P_{bronch}), a sterile plastic catheter with an OD of 1.1 mm and a length of 90 cm (Epidural Catheter 16 G with three lateral eyes, Portex, Smith medical, Keene, USA) was placed inside the DLTs' bronchial limb. Insertion of the bronchial pressure catheter (BPC) into the DLT's bronchial lumen was realized with a specially manufactured connector (Fig. 1. BOX). Insertion depth of the BPC was determined beforehand in the sterile setup. The pressure gradient across the DLT's bronchial lumen (ΔP_{DLT}) was calculated in terms of the root means square difference (RMSD) over the entire breathing cycle. Respiratory and haemodynamic variables were measured for at least 15 consecutive breaths, after five min of equilibration time at each I:E ratio.