Journal of Clinical Anesthesia (2015) **27**, 445–450

Journal of Clinical Anesthesia

Original Contribution

Effects of a 1:1 inspiratory to expiratory ratio on respiratory mechanics and oxygenation during one-lung ventilation in patients with low diffusion capacity of lung for carbon monoxide: a crossover study☆

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Received 25 February 2015; revised 5 April 2015; accepted 9 June 2015

Keywords:
One-lung ventilation;
inspiratory-expiratory ratio;
oxygenation;
respiratory mechanics

Abstract

Study Objective: To investigate the effects of a 1:1 inspiratory-to-expiratory (I:E) ventilation ratio on oxygenation and respiratory mechanics during one-lung ventilation (OLV) in patients with low diffusion capacity of lung for carbon monoxide (DLCO).

Design: Prospective, randomized, crossover study.

Setting: Operating room, university hospital.

Patients: Twenty-six patients with a preoperative DLCO less than 80% who were scheduled for lung lobectomy requiring OLV under general anesthesia.

Interventions: In the first group (n = 13), OLV was begun with a 1:1 I:E ratio, which was switched to a 1:2 I:E ratio after 30 minutes. In the second group (n = 13), the modes of ventilation were performed in the opposite order. Pressure-controlled ventilation with 5 cm H_2O of positive end-expiratory pressure and a tidal volume of 5 to 8 mL/kg was applied during OLV.

MeasurementsArterial and central venous blood gas analyses were recorded and used to calculate intrapulmonary shunt fraction and physiologic dead space. These measurements were taken at 4 time points: 10 minutes after two-lung ventilation in the lateral decubitus position, 30 minutes after initiation of OLV, 30 minutes after switching the I:E ratio, and 10 minutes after two-lung ventilation was resumed.

Main Results: There was no difference in arterial oxygen tension during OLV between the 2 groups ($P = .429$). Arterial carbon dioxide tension and peak airway pressure were lower in the 1:1 group than in the 1:2 group ($P = .003$; $P = .008$). Physiologic dead space was also decreased in the 1:1 I:E ratio group ($P = .003$). Mean airway pressure and dynamic compliance were higher in the 1:1 group ($P = .003$; $P = .007$).

☆ There are no competing interests or external funding to be declared.

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http://dx.doi.org/10.1016/j.jclinane.2015.06.012

Conclusions: Pressure-controlled ventilation with a 1:1 I:E ventilation ratio did not improve oxygenation in patients with low DLCO during OLV compared with a 1:2 I:E ventilation ratio. However, it did provide benefits in terms of respiratory mechanics and increased the efficiency of alveolar ventilation during OLV.

1. Introduction

One-lung ventilation (OLV) is required for a variety of thoracic surgeries involving the lungs, esophagus, aorta, and mediastinum. Studies have suggested, however, that hypoxemia can occur in up to 5% to 10% of patients undergoing OLV, which may present a serious challenge to patient safety [1].

Use of a prolonged inspiratory-to-expiratory (I:E) ratio method was originally developed to improve oxygenation in patients with reduced lung function, as in cases of acute lung injury or acute respiratory distress syndrome (ARDS) [2]. A single previous study suggests that applying a 1:1 I:E ratio increases arterial oxygenation [3]. The basis of this practice is that longer inspiratory times increase the gas flow to the alveoli of slow time constants, thereby improving oxygenation [4]. However, our previous study, which applied volume-controlled ventilation (VCV) with a 1:1 I:E ratio during OLV, showed no improvement in oxygenation when compared with the conventional 1:2 I:E ventilation ratio [5]. One possible explanation of this result is that because enrolled patients had otherwise normal lung function, one healthy lung could provide sufficient oxygenation during OLV without resulting in hypoxemia. Thus, we hypothesized that the application of a 1:1 I:E ratio during OLV in patients with compromised lung function would have a positive impact on oxygenation when compared with the conventional 1:2 I:E ratio.

Generally, decreased diffusion capacity of lung for carbon monoxide (DLCO) is useful for detecting patients with restrictive lung disease, especially intrinsic type. DLCO reflects the gas exchange function of the lungs by determining whether gas can move from the alveoli, across the interstitium, and into the blood. It is performed by having the patient breathe in carbon monoxide (CO), which binds to hemoglobin. To reach the hemoglobin, the CO must diffuse across the alveolar-blood barrier. If there is thickening of the alveoli or interstitium, diffusion will be impaired, resulting in a decreased DLCO. Studies show that even in subjects with otherwise normal pulmonary function, diffusion capacity has a role in predicting postoperative morbidity [6,7]. Thus, we concluded that DLCO is an appropriate indicator for identifying patients with reduced lung function.

The primary aim of this study was to investigate the effects of a minimally prolonged 1:1 I:E ventilation ratio on oxygenation compared with the conventional 1:2 I:E ventilation ratio used during OLV in patients with reduced preoperative DLCO undergoing thoracoscopic lung lobectomy. In addition, we evaluated respiratory mechanics and hemodynamic changes to compare the effects of this different I:E ratio during OLV.

2. Methods

This study was approved by the Institutional Review Board of Severance Hospital, Yonsei University Health System (ref: 1-2011-0058). After written informed consent was obtained from all participants, 26 patients aged 24 to 77 years with the American Society of Anesthesiologists physical status of II to IV who were scheduled for thoracoscopic lung lobectomy requiring OLV under general anesthesia were enrolled in this study. All patients underwent preoperative pulmonary function tests before surgery, and those with a DLCO more than 80% of the predicted value were excluded. Patients with a history of coronary artery occlusive disease, cerebrovascular disease, renal insufficiency, tobacco abuse, and obesity (body mass index >30 kg/m^2) were also excluded. The patients were randomly assigned into 2 groups. In the first group (n = 13), OLV was begun with a 1:1 I:E ratio and then switched to a 1:2 I:E ratio after 30 minutes. In the second group (n = 13), the mode of ventilation was performed in the opposite order. This randomized controlled trial took place at the surgery center of Severance Hospital in Seoul, Korea, between February and December 2012.

All patients received midazolam 0.04 mg/kg via intramuscular route (maximum dose, 2.5 mg) for premedication. Standard monitoring devices were applied after arrival in the operating room. Anesthesia was induced with 1.5 mg/kg propofol and 1.0 μg/kg remifentanil. Tracheal intubation with a left-sided double-lumen tube (Broncho-Cath; Mallinckrodt Medical, Inc, Athlone, Ireland) was facilitated with 0.9 mg/kg rocuronium, and the position of the double-lumen tube was confirmed with a fiberoptic bronchoscope. The lungs were initially ventilated in pressure-controlled ventilation (PCV) mode (Zeus ventilator, Dräger Medical, Lübeck, Germany) with a tidal volume of 5 to 8 mL/kg, an I:E ratio of 1:2, a respiratory rate of 8 to 12 breaths per minute of 100% oxygen, and a positive end-expiratory pressure (PEEP) of 5cm H_2O. The tidal volume and the respiratory rate were controlled to adjust the end-tidal carbon dioxide in the range of 38 ± 2 mm Hg, and after the appropriate tidal volume and respiratory rate were found, the settings were fixed during the measurement periods. After induction of anesthesia, a 20-gauge radial artery catheter was placed, and a 7F central venous catheter (Arrow International,