Effect of Ventilation Mode on Gas Exchange during Partial Liquid Ventilation at Different Perfluorocarbon Doses in Surfactant-Depleted Lung

C.-M. Lim,1 S.-H. Yang,1 J.-L. Kang,2 and Y. Koh1

1Division of Respiratory and Critical Care Medicine, University of Ulsan College of Medicine, Seoul, Korea 138-600; 2Department of Physiology, College of Medicine, Ewha Womans University, Seoul, Korea

Abstract. Although gas ventilation is an integral part of partial liquid ventilation (PLV), the role of ventilation mode during PLV is not established, especially at a varying perfluorocarbon dose. In 10 surfactant-depleted rabbits, PLV was performed at a low dose (10 ml/kg) and at a functional residual capacity (FRC) dose (30 ml/kg) of perflurodecalin in pressure-control (PC) and volume-control (VC) modes in balanced sequence. In these four PLV trials, PC mode was adjusted to be identical to VC mode with regard to tidal volume and inspiratory-to-expiratory ratio. PaO2 during PLV in PC mode was higher than in VC mode at the Low dose (159 ± 93 mm Hg, 115 ± 75 mm Hg, respectively; p = 0.005) and at the FRC dose (228 ± 114 mm Hg, 164 ± 104 mm Hg, respectively; p = 0.002). PaCO2 during PLV in PC mode was lower than in VC mode at the Low dose (59 ± 18 mm Hg, 72 ± 20 mm Hg, respectively; p = 0.005), whereas PaCO2 at the FRC dose was not different between modes. Curves of inspiratory flow appeared least deformed with PLV in PC mode at the Low dose, whereas they were saw-tooth deformed with PLV in VC mode at both doses. Actual time for inspiratory gas flow during PLV was shorter in PC mode compared with VC mode at both doses. In conclusion, in surfactant-depleted rabbit, gas exchange during PLV was better with PC mode compared with VC mode, especially at a low perfluorocarbon dose. Given the same tidal volume, PC appeared to insufflate the perfluorocarbon-filled lung better than VC at both low and FRC doses of perfluorocarbon.
Key words: Partial liquid ventilation—Perfluorocarbon dose—Ventilation mode—Gas exchange—Inspiratory flow

Introduction

Partial liquid ventilation (PLV) has been shown to be effective in acute lung injury/acute respiratory distress syndrome (ALI/ARDS) for gas exchange/lung mechanics [6, 13, 18], tissue protection [7, 17, 22], and possibly for the attenuation of ventilator-induced lung injury [2]. In principle, PLV comprises a perfluorocarbon-filled lung and a mechanical ventilator, the latter functioning as an in vivo gas exchanger for perfluorocarbon liquid [3]. Because this hybrid system implies an interaction between incoming gas and resident liquid, ventilation mode (the primary determinant of inspiratory gas flow of a ventilator) may affect gas exchange outcome of PLV. However, the role of ventilation mode in PLV in this regard has not been fully understood yet, especially at varying perfluorocarbon doses.

Pressure control (PC) mode and volume control (VC) mode are the two basic ventilatory modes in most conventional ventilators. It was suggested in previous studies that a high inspiratory flow rate from mechanical ventilators improves the efficiency of gas exchange during PLV [4, 14]. Because PC mode provides a higher peak inspiratory flow than VC mode for a given tidal volume [15], we assumed that gas exchange during PLV could be better with PC mode than with VC mode.

During PLV, a variety of situations may occur with regard to the volume of perfluorocarbon indwelling the lung because of adoption of a low dose, evaporative loss of the liquid over time, or transition from or back to gas ventilation [2, 8–10, 14, 16, 24]. In these situations, it is likely that the influence of ventilator variables on the outcome of PLV may also vary in intensity. The smaller the volume of perfluorocarbon in the lung, the greater the role of a ventilator variable would be, and vice versa.

Therefore, we thought it worthwhile to investigate whether PLV in PC mode results in a better gas exchange than PLV in VC mode, and also whether this effect of ventilatory mode during PLV, if any, assumes different significance according to the amount of perfluorocarbon present in the lung.

Materials and Methods

Animal Preparation

Ten New Zealand white rabbits (8 males, 2 females) (3.1 ± 0.2 kg) were used for this study. The study protocol was approved by our Institutional Board of Animal Care Committee. Rabbits were cared for and handled according to the guidelines of the USA National Institute of Health. The rabbits were anesthetized with xylazine 5 mg/kg IM and ketamine 30 mg/kg IM followed by an IV infusion of the mixture of ketamine 75 mg and xylazine 10 mg in 20 ml normal saline at a rate of 0.4–0.6 ml/min through an ear vein. Pancuronium 0.1 mg/kg was intermittently given IV to prevent spontaneous