

Title: OPTIMUM PEEP DETERMINED BY ARTERIAL-END TIDAL CARBON DIOXIDE GRADIENT

Authors: I.P. Murray, M.D., J.H. Modell, M.D., T.J. Gallagher, M.D., and M.J. Banner, R.R.T.

Affiliation: Departments of Anesthesiology and Surgery, University of Florida College of Medicine, Gainesville, Florida 32610

**Introduction.** Positive end-expiratory pressure (PEEP) has been shown to increase functional residual capacity, to decrease intrapulmonary shunting ( $Q_{sp}/Q_t$ ), and to improve oxygenation in patients with adult respiratory distress syndrome. How much PEEP should be applied and how its maximal benefit should be assessed has been a matter of debate. The two most commonly used methods are to determine the level of PEEP, either by its effect on compliance (best PEEP)<sup>1</sup> or by the lowest  $Q_{sp}/Q_t$  (optimum PEEP).<sup>2,3</sup> The first method titrates PEEP to changes in lung mechanics and the second to the exchange of oxygen between air and blood. Neither technique considers the optimum removal of carbon dioxide nor the contribution of dead space to ventilation/perfusion ratios. With either the best PEEP or the optimum PEEP method, excessive PEEP can detrimentally decrease perfusion and increase dead space; thus, some method to easily detect these changes is required.

**Methods.** Ten dogs anesthetized with sodium pentobarbital were connected to a volume limited ventilator set to deliver a tidal volume of 15 ml/kg and a fractional concentration of inspired oxygen of 0.5. Respiratory rate was between 8 and 12/min to keep  $PaCO_2$  between 35 and 45 mmHg. End tidal carbon dioxide tension, femoral artery and pulmonary artery blood pressures, and central venous and mean airway pressures were recorded continuously. Arterial and mixed venous pH,  $PO_2$ , and  $PCO_2$  were measured and  $Q_{sp}/Q_t$  and cardiac output were calculated. After control measurements, 0.075 mg/kg of oleic acid was injected intravenacavally. Measurements were repeated 90 min later. Then PEEP was added in 5-mmHg increments up to 25 mmHg and measurements and calculations were made after each increase in PEEP. Data were analyzed by Student's *t* test and a *p* less than 0.05 was considered significant.

**Results.** In all animals, the  $Q_{sp}/Q_t$  returned to pre-oleic acid levels, but the level of PEEP necessary for such improvement varied from animal to animal. Cardiac output progressively decreased with each increase of PEEP added to the mechanically ventilated dogs. Arterial oxygen tension increased as  $Q_{sp}/Q_t$  improved and plateaued as  $Q_{sp}/Q_t$  decreased to clinically insignificant levels. The gradient between arterial carbon dioxide tension and end tidal carbon

dioxide tension ( $PaCO_2 - PetCO_2$ ) increased significantly after the injection of oleic acid. This gradient decreased in all dogs when they were treated with PEEP. In eight dogs,  $PaCO_2 - PetCO_2$  began to increase again as higher levels of PEEP were applied. Compliance did not respond consistently to PEEP. In eight animals, the lowest  $PaCO_2 - PetCO_2$  was recorded when the  $Q_{sp}/Q_t$  was lowest and, in the other two, the  $Q_{sp}/Q_t$  was within 3 per cent of its lowest measured value. Likewise, six of the dogs had the highest  $PaO_2$  recorded when the  $PaCO_2 - PetCO_2$  was lowest. The  $PaO_2$  was within 13 per cent of its highest value in the other four animals at the minimum  $PaCO_2 - PetCO_2$ .

**Discussion.** These results suggest that the minimum  $PaCO_2 - PetCO_2$  obtainable represents the point of lowest dead space and of greatest ventilation/perfusion matching, a condition that defines "optimum PEEP" more precisely. A secondary increase in  $PaCO_2 - PetCO_2$  as higher than optimum PEEP is applied suggests a redistribution of blood flow and an increase in dead space. Thus, too much PEEP can be applied and can adversely affect perfusion and possibly cardiac output. This cannot be monitored by measuring either  $Q_{sp}/Q_t$  or  $PaCO_2$  alone. The  $PaCO_2 - PetCO_2$  can be measured by determining the carbon dioxide in exhaled gas and arterial blood, which does not demand the more invasive pulmonary artery catheter. Furthermore, if the state of the art in skin electrodes continues to improve, optimum PEEP could be determined noninvasively by measuring exhaled  $PCO_2$  and cutaneous  $PCO_2$  in lieu of  $PaCO_2$ .

#### References.

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