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TITLE : AIRWAY CLOSURE, PEEP, AND $AaDO_2$ DURING ANESTHESIA

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Several currently popular explanations for pulmonary dysfunction during anesthesia involve changes in the relationship between closing capacity (CC) and functional residual capacity (FRC). Effects of PEEP during anesthesia are disputed. In the present study we have attempted to determine whether oxygenation can be improved in anesthetized patients by adjusting the level of FRC with PEEP using (CC-FRC) relationship as a guide.

Methods. This study was approved by the local human research committee. Twenty-two consenting patients receiving general endotracheal anesthesia for elective surgery were artificially ventilated at a rate of 10/min and a tidal volume of 10 ml/kg. F_IO_2 was maintained at 0.40 ± 0.01, the balance being anesthetic gases. After 30 min arterial blood gases were measured.

(CC-FRC) was measured by a method described previously (1) using a bolus of N_2 as the indicator gas. The endotracheal tube was connected to the measuring circuit and pressure within the respiratory system (Pao) continuously monitored on an oscilloscope. One operator reduced Pao by controlled suction to residual volume (RV), which was arbitrarily defined for this study as -20 cm H_2O. At this point another operator introduced a bolus of air into the lungs. Rotation of a valve placed the lungs in communication with a 7-liter syringe previously filled with 100% O_2. (The syringe was gas tight on both sides of the piston so that pulmonary inflation or deflation displaced identical gas volumes at identical flows into or out of an associated wedge spirometer. This permitted measurement of these volumes and flows using the respective transducers on the spirometer.) The lungs were slowly inflated with 100% O_2 to total lung capacity (TLC), which was arbitrarily defined as +35 cm H_2O. Deflation from TLC to RV then occurred at a controlled flow of 0.25 to 0.30 l/s. During deflation, Pao, expiratory flow rate, and exhaled N_2 concentration as measured with an N_2 analyzer, were displayed as functions of volume using the storage oscilloscope. Artificial ventilation of the patient was then resumed and the image on the oscilloscope screen was inspected and photographed.

CC was identified as the first convincing final departure of the N_2 tracing from the alveolar plateau. FRC was identified as the point where Pao was 0. With this simultaneous determination of point of airway closure and FRC, (CC-FRC) could be read directly from the oscilloscope. The amount of pressure required to bring FRC above CC could also be read directly.

Patients who exhibited airway closure below FRC then had 5 cm H_2O PEEP applied and patients closing above FRC received enough PEEP to bring FRC above CC using 5, 7½, or 10 cm H_2O Boehringer PEEP valves. After 20 min of PEEP, arterial blood gases were again obtained. In some patients an additional (CC-FRC) measurement was made immediately after discontinuing PEEP. In most patients arterial blood gases were obtained 20 min after discontinuing PEEP. Exact (CC-FRC) for each patient was determined subsequently from photographs by four independent workers experienced in interpreting closing volume measurements. PAO_2 was calculated assuming a respiratory exchange ratio of 0.8. Alveolar-arterial oxygen tension difference ($AaDO_2$) was then calculated. (CC-FRC) data but not blood gases from 15 additional patients studied in 1975 using this identical technique were also included in analysis not requiring arterial blood gas data.

Results and Discussion. In this group of anesthetized subjects (CC-FRC) significantly increased with age ($P<0.001$). CC and FRC coincided at about age 41. The regression equation for our patients was: (CC-FRC) (liters) = 0.014 x age - 0.572. This is in excellent agreement with the equation presented by Juno et al. (2). $AaDO_2$ decreased with application of PEEP in 18 of 22 patients. Mean $AaDO_2$ ($F_IO_2 = 0.4$) for all 22 patients was 78 mm Hg with ZEEP and 63 mm Hg with PEEP. The decrease was significant ($P<0.005$). If the patients were separated into those who exhibited airway closure above or below FRC it was found that the mean 9 mm Hg decrease in $AaDO_2$ caused by PEEP in younger subjects closing below FRC was not significant whereas the 20 mm Hg decrease in older patients closing above FRC was significant ($P<0.005$). After removal of PEEP (CC-FRC) resumed its control value immediately but $AaDO_2$ remained significantly smaller than control ($P<0.025$) for at least 20 min. Other relationships were investigated where a strong association was suggested but where the data barely failed to attain customary levels of significance ($0.1>P>0.05$). These included relationships between age and control $AaDO_2$, and between (CC-FRC) and control $AaDO_2$. Such relationships would be expected to occur. Additional patients are currently being studied to determine if significance in these relationships can be attained with a larger sample size.

We conclude that, in general, patients less than about 41 years of age are not expected to exhibit airway closure above FRC during anesthesia. The judicious use of PEEP can decrease $AaDO_2$ in those anesthetized patients who exhibit airway closure above FRC. It is also possible that "best PEEP" or "optimal PEEP" is the amount of PEEP which is required to bring FRC above CC.

1. Waltemath CL and Bergman NA: Measurement of closing volume in apneic subjects. Crit Care Med 4:139, 1976.
2. Juno P, Marsh HM, Knopp TJ and Rehder K: Closing capacity in awake and anesthetized, paralyzed man. J of Appl Physiol 44:238, 1978.

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