Title: ALVEOLAR DEAD SPACE VENTILATION DOES NOT AFFECT NON-INVASIVE DETERMINATIONS OF WIDELY VARIABLE CARDIAC OUTPUT IN YOUNG PIGS

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Introduction. Pulmonary blood flow, and therefore cardiac output (CO), can be determined in infants and children using a non-invasive rebreathing maneuver and the Fick CO_2 equation.[1] In the present study, we determined the effects of variation in CO and alveolar deadspace ventilation (V_D/V_T) on the accuracy of these determinations in small subjects.

Methods. After approval from our Animal Care and Use Committee, we studied 14 pigs weighing 5.9-11.4 kg. Twelve were supine and 2 were in various positions in order to increase V_D/V_T. Anesthesia was induced and maintained with N_2O/O_2/halothane. Muscle relaxation was maintained with pancuronium and d-tubocurare. A cuffed endotracheal tube was inserted and ventilation was controlled with a Siemens-Elema 900 D ventilator. Respiratory volumes and CO_2 production ($\dot{V}CO_2$) were measured by the ventilator and Siemens-Elema 930 CO_2 analyzer. Inspired and expired PCO_2 (P_ICO_2, $PetCO_2$) were sampled from the distal end of the endotracheal tube and measured by infrared analysis. Catheters were inserted into a 1) jugular vein 2) carotid artery for sampling of arterial PCO_2 ($PaCO_2$) and 3) pulmonary artery (confirmed at autopsy) for measurement of mixed venous PCO_2 ($P\bar{v}CO_2$) and invasive cardiac output (ICO) by thermodilution. In 9 pigs, non-invasive cardiac output (NICO) was determined using the Fick equation ($CO = \dot{V}CO_2/C\bar{v}CO_2 - CaCO_2$, where $C\bar{v}CO_2$ = mixed venous CO_2 content and $CaCO_2$ = arterial CO_2 content), a modified McHardy equation [$C\bar{v}CO_2 - CaCO_2 = 11.02(P\bar{v}CO_2^{0.396} - PetCO_2^{0.396}) - 0.015(P\bar{v}CO_2 - PetCO_2)(15 - \text{hemoglobin})$], and the third breath (RB3) of a rebreathing (RB) maneuver to estimate the $P\bar{v}CO_2$.[1] In addition, $P\bar{v}CO_2$ was estimated and NICO was determined from the third (NRB3), fourth (NRB4), and fifth (NRB5) breaths of 5 pigs ventilated with 15% CO_2 in N_2O/O_2 for 5 breaths using a non-rebreathing (NRB) circuit. $P\bar{v}CO_2$ was estimated as the x-intercept of $PetCO_2 - P_ICO_2$ plotted against P_ICO_2. Hemoglobin was estimated as hematocrit/3. CO was varied by changing the depth of anesthesia, administration of phentolamine, and removal of blood. V_D/V_T was calculated using the Bohr equation minus equipment and anatomic deadspaces. NICO was compared with ICO using linear regression analysis and ICO was compared graphically with V_D/V_T.

Results. The mean ± SD difference between estimated and measured $P\bar{v}CO_2$ [$\Delta P\bar{v}CO_2$(est-meas)] was 9.5 ± 5.4 mm Hg. There were good correlations between NICO and ICO for both RB and NRB methods (Table). NRB4 had the best agreement with the line of identity (Fig. 1). Increasing V_D/V_T did not change the relationship between NICO and ICO (Fig. 2).

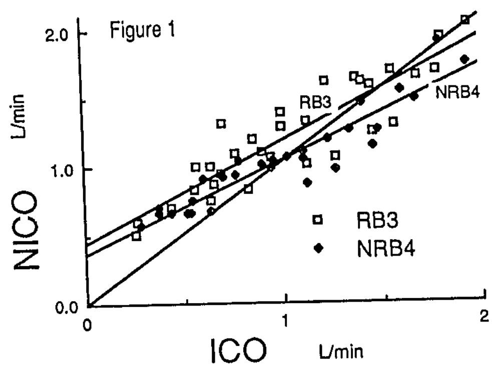
Discussion. The presence of a positive $\Delta P\bar{v}CO_2$(est-meas) agrees with existing data and is of uncertain etiology.[2] Nevertheless, estimated $PvCO_2$ values provide accurate NICO determinations over a wide variation of CO in small subjects. Accurate NICO measurements with increased V_D/V_T suggests that V_D/V_T affects estimated $PvCO_2$ and $PetCo_2$ proportionately. The NRB method lends itself easily to automation and may be more accurate than the RB method especially at low CO.

References.

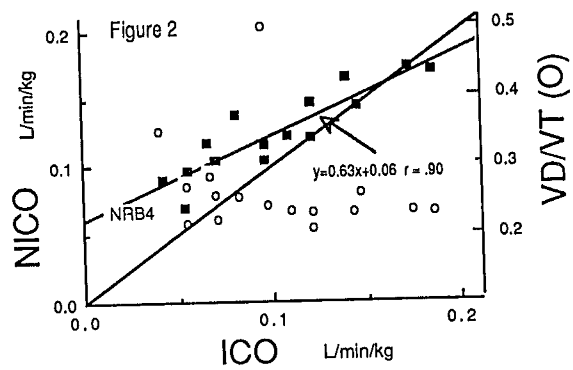
1. Morton WD. Anesthesiology 1987;67:A486
2. Yu CJ, Lutherer B, Guyatt AR, Otis AB. Respir Physio 1973;17:162-177

Table

Breath #	y value	r value
RB3	0.75x+0.44	0.90
NRB3	0.75x+0.46	0.93
NRB4	0.68x+0.37	0.94
NRB5	0.70x+0.26	0.93



Data From 3 Pigs Using Both RB3 And NRB4



Data From A 6.4 kg Pig With Positional Changes