Title: V_D/V_T, Qs/Qt AND THE END-TIDAL TO ARTERIAL PCO_2 GRADIENT

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Introduction: The end-tidal to arterial PCO_2 gradient (ΔPCO_2) results from two factors; the dead space to tidal volume ratio (V_D/V_T) and the venous admixture (Qs/Qt). An increase in either increases the ΔPCO_2. Children with congenital heart disease (CHD) have abnormalities of both V_D/V_T and Qs/Qt which result in an increased ΔPCO_2.[1] The relationship of the ΔPCO_2 to the V_D/V_T and Qs/Qt has not been investigated. The purpose of this study was to examine the relationship of the V_D/V_T and Qs/Qt to the ΔPCO_2 in children with CHD.

Methods: After approval from the Committee on Human Research 41 patients with cyanotic or acyanotic CHD scheduled for palliative or corrective cardiac surgery were studied (Table). The patients were divided into 4 groups: no structural intracardiac anomalies (normal group); acyanotic with increased pulmonary blood flow (PBF) (acyanotic group); cyanotic with increased PBF (cyanotic (I) group); and cyanotic with decreased PBF (cyanotic (D) group). After induction of general anesthesia with fentanyl ventilation was controlled with an Air Shields Ventimeter and Mapleson B breathing circuit. Anesthesia was maintained with fentanyl 6 µg/kg/hr. Ventilatory parameters were adjusted to provide a $PaCO_2$ in the clinical range (30-35 mm Hg). The study was performed after sternotomy with the patient in the supine position at 37°C rectal temperature. The patients were ventilated undisturbed for 5 minutes to obtain steady state conditions. Arterial and mixed venous blood (direct puncture) were drawn simultaneously with the recording of the distal end-tidal PCO_2 ($PetCO_2$). $PetCO_2$ was measured by infrared analysis (Puritan-Bennett). To calculate mixed expired PCO_2, expired gas was collected in a Douglas bag using a two-way non-rebreathing valve. $PetCO_2$ was corrected for barometric pressure and water vapour pressure. V_D/V_T and Qs/Qt were calculated using standard formulae.[2] The relationship between $PetCO_2$ and $PaCO_2$; ΔPCO_2 and V_D/V_T; ΔPCO_2 and Qs/Qt; V_D/V_T and Qs/Qt were determined by least squares linear regression. Slopes and elevations were compared using Student's t-test. Multiple linear regression analysis determined the relationship between ΔPCO_2, Qs/Qt and V_D/V_T. Statistical significance was accepted at $p < 0.05$.

Results: $PetCO_2$ underestimated the $PaCO_2$ in all patients studied with a mean (± SD) ΔPCO_2 of 7.46 (± 4.87). The $PetCO_2$:$PaCO_2$ relationship for the 4 groups is demonstrated in Figure 1. There was no statistical difference between the line of regression and the line of identity for the normal and acyanotic group of patients, but there was a statistical difference for the cyanotic (I) and cyanotic (D) groups of patients. The ΔPCO_2 increased as the V_D/V_T and Qs/Qt increased and their relationship is described by the multiple linear regression equation: $\Delta PCO_2 = 1.55 + 10.91$ (Qs/Qt) + 13.38 (V_D/V_T) ($r^2 = 0.69$).

Discussion: The $PetCO_2$ underestimates the $PaCO_2$ in children with CHD. The $PetCO_2$ serves as an acceptable estimate of $PaCO_2$ in normal and acyanotic groups of patients, but significantly underestimates the $PaCO_2$ in cyanotic (I) and cyanotic (D) groups of patients. The ΔPCO_2 increases as V_D/V_T and Qs/Qt. V_D/V_T is the primary determinant of the ΔPCO_2, but Qs/Qt becomes increasingly important as the magnitude of the Qs/Qt increases.

References:

1. Lindhal SGE, Yates AP, Hatch DJ. Anesthesiology 66:168-175, 1987
2. Nunn JF. Applied Respiratory Physiology. Second edition. London, Butterworths, 1978, pp 274-309, pp 227-32

TABLE

	AGE	WEIGHT	Hct
Normals (n = 9)	6.21 ± 4.29	19.78 ± 14.46	36.76 ± 2.89
Acyanotic (n = 9)	6.05 ± 2.85	16.48 ± 7.58	36.26 ± 4.28
Cyanotic (I) (n = 9)	5.18 ± 3.23	16.48 ± 11.15	46.38 ± 7.03*
Cyanotic (D) (n = 14)	5.88 ± 2.39	16.67 ± 7.67	50.32 ± 7.56*

*$p \leq 0.05$ different from the normal and acyanotic group

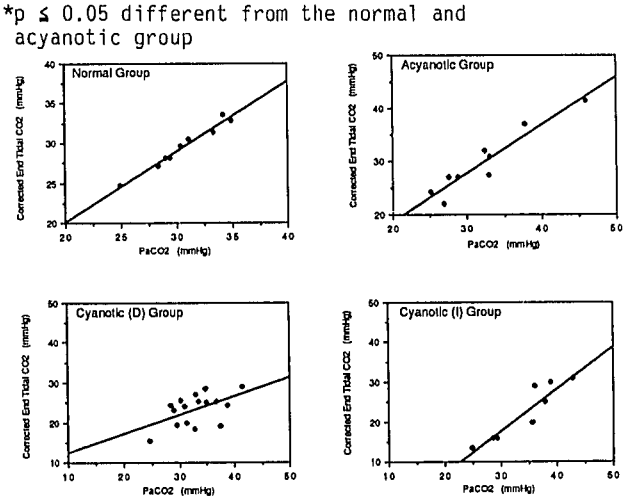

Figure 1: $PetCO_2$ vs. $PaCO_2$ for the four groups. Lines of regression are represented by (——) and described by the formulae: normal group $y = 2.5 + 0.88x$ ($R^2 = 0.96$); acyanotic group $y = 0.61\ 0.91x$ ($R^2 = 0.90$); cyanotic (I) group $y = 14.21 + 1.06x$ ($R^2 = 0.83$); cyanotic (D) group $y = 7.88 + 0.47x$ ($R^2 = 0.27$).

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