ESTIMATING ARTERIAL PCO₂ FROM FLOW-WEIGHTED AND TIME-AVERAGE ALVEOLAR PCO₂ DURING EXERCISE

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The appropriateness of the ventilatory response to muscular exercise is best considered with respect to the precision of arterial PCO₂ (PₐCO₂) regulation for moderate exercise and by the degree of the compensatory hyperventilation at work rates which engender a metabolic acidemia. But in order to avoid the necessity for intra-arterial sampling, which for sufficient data-density usually requires an indwelling catheter, several investigators have proposed non-invasive techniques for PₐCO₂ estimation. Techniques which are based upon assumptions of dead space volume (V₀) or of a constant relationship between PₐCO₂ and end-tidal PCO₂ (PₑₗₜCO₂) are not useful owing to the large inter-subject variability in the former case¹ and the invalidity of the assumption in the latter.²,³ DuBois et al.⁴ proposed that the mean alveolar PCO₂ could be derived from a "reconstruction" of the intra-breath time profile of PₐCO₂ (i.e., time-average: PₐCO₂ᵀ), which in normal subjects would closely approximate PₐCO₂. Cumming,⁵ has shown that when the cumulative CO₂ output (VCO₂) is expressed as a function of the cumulative expired volume (V), the resulting relationship is - to a very close approximation - linear (following a small lag phase) with a slope which represents PₐCO₂ (i.e., flow-weighted average: PₐCO₂ᵀ) and an intercept on the volume axis which is a measure of the "series" dead space (V₀). We were interested, therefore, in developing on-line, breath-by-breath techniques for determining these estimators and to define the accuracy with which they reflect directly-measured PₐCO₂ during exercise.
METHODS

Inspiratory and expiratory airflow and volume were monitored continuously by pneumotachography or with a bidirectional turbine volume sensor. Respired gas tensions were determined by mass spectrometry. Either on- or off-line processing of the resulting analog signals by digital computation provided the intra-breath gas-exchange profiles.

![Graph](image)

**Fig. 1.** Continuous recording of inspiratory flow ($V_{\text{insp}}$), expiratory flow ($V_{\text{exp}}$), respired PCO$_2$, respired PO$_2$ and EKG during steady-state, constant-load exercise (150 W). Reconstructed profile of alveolar PCO$_2$ (dotted profile) is superimposed on the respired PCO$_2$ trace. Solid vertical lines indicate start of inspiration; dashed vertical lines indicate temporal correction for transit delay to mass spectrometer.

$P_{\text{A}}$CO$_2^T$ was estimated from the time course of expired PCO$_2$ (Fig. 1), the "alveolar" phase of which was extrapolated back to the start of expiration. These profiles are commonly quite linear during exercise,$^6,7$ but for those cases in which the alveolar phase was curvilinear we extrapolated the actual contour to expiratory onset. Several corrections need to be applied to the position of the expiratory $P_{\text{A}}$CO$_2$ contour: (a) the temporal delay caused by transit through the sampling tube of the mass spectrometer (Fig. 1: dashed vertical line); (b) the short transport delay between the alveoli and the mouth (Fig. 1) which requires a small leftward displacement of the dotted contour from the measured alveolar profile; and (c) a small and, we have found, quantitatively-negligible effect of the momentarily-stable region of $P_{\text{A}}$CO$_2$ after inspiratory onset which is related to the time required for ambient air to traverse the end-expiratory dead