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Title: VALIDATION OF A BREATH-BY-BREATH METHOD FOR MEASURING RESPIRATORY QUOTIENT

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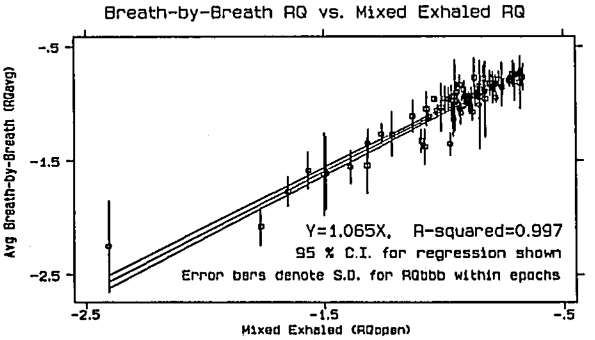
Introduction: Measurement of respiratory quotient (RQ), or respiratory exchange ratio for CO_2, is useful as an indicator of changes in CO_2 equilibrium, as with hyperventilation, as an early sign of hypoventilation, and as an indicator of important metabolic states, such as net lipogenesis.[1,2,3] RQ can be calculated from the ratio of O_2 consumption (VO_2) to CO_2 production (VCO_2), both of which require the measurement of exhaled or inhaled volumes. Measurement of volume is mathematically unnecessary when the ratio of VCO_2/VO_2 is calculated using the Haldane or other transformation on mixed exhaled gas. Since precise measurement of minute volumes is technically difficult, especially in infants, and since collection of mixed exhaled gas requires bulky equipment,[4] we sought to validate a method of breath-by-breath RQ based upon real-time analysis of inspired and alveolar gas alone.

Methods: Approval of the hospital and medical school Institutional Review Boards was obtained. Data from 1804 breaths from 25 healthy adult volunteers for a total of 79 epochs were collected. To obtain a range of RQ values from -0.7 to -2.0, we tested subjects breathing room air during epochs after an overnight fast, after consumption of approximated 2 gm/kg glucose, and during aerobic exercise. Simultaneous collection of breath-by-breath (volumeless, RQbbb) and mixed-exhaled (open circuit, RQopen) data was accomplished with a personal computer. Airway and mixed-exhaled gas composition was analyzed using raman spectroscopy (Albion/Ohmeda RASCAL) with calibration to known standards for each subject. Post-hoc data reduction and correlation analysis was performed (STATA, Computing Resource Center).

Results: RQ values from -0.6 to -2.4 were obtained. Breath-by-breath RQ was calculated with and without N_2 measurement; no significant relationship between RQopen and RQbbb existed if correction for Vi-Ve was done without N_2 measurement. Within epochs, RQbbb varied widely around the corresponding RQopen, reflecting the differences in gas exchange between breaths. Averaging RQbbb over each epoch (RQavg) produced data which was regressed against RQopen with R-squared of 0.91 ($p<0.001$). Because the constant term for the regression was insignificantly different from zero ($p=0.079$), the regression was forced with a zero intercept, yielding R-squared of 0.997 ($p<0.001$).



Discussion: Online analysis of airway gases shows the variability of RQ from breath to breath, a sensitive indicator of changes in ventilation.[1] When averaged over a number of breaths, a very close approximation of mixed-exhaled RQ is obtained, useful for tracking changes in CO_2 stores and metabolism, and in detection of inappropriate nutritional therapy.[4] Inclusion of breath-by-breath nitrogen analysis improves the reliability of the Haldane transformation for environments with high FiO_2, or with changing quantities of other gases (helium, N_2O, anesthetic vapors).[5,6]

References:
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2. J. Clin. Monit. 5:149, 1989.
3. Crit. Care. Med. 17:345, 1989.
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EFFECT OF PEEP ON THE FENTANYL-INDUCED MODIFICATIONS OF THE RESISTIVE PROPERTIES OF THE RESPIRATORY SYSTEM.

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Fentanyl was shown[1] to increase the airflow resistance of mechanically ventilated, myorelaxed normal patients under intravenous anesthesia by proportionnally increasing Raw and the additionnal resistance ΔR. ΔR is due to the visco-elastic properties of the thoracic tissues and/or to a pendelluft phenomenon. The effect of fentanyl on Raw was consistent with a bronchoconstrictive challenge which may increase a pendelluft. Since pendelluft is expected to decrease with a increase in lung volume, the effect of a mild level of PEEP on the fentanyl induced modification of ΔR was studied by the end-inflation occlusion method.

Ten ASA I men (35±8.8 yrs, 77.5±7.7 kg) scheduled for testicular surgery were selected. After midazolam 5mg I.M. on call, anesthesia was induced with methohexital (2.8±0.42 $mg.kg^{-1}$) fentanyl (4.91±0.13$\mu g.kg^{-1}$) vecuronium bromide (0.15 $mg.kg^{-1}$) with maintenance with an infusion of methohexital (0.1 $mg.kg^{-1}.min^{-1}$) and an additionnal dose of fentanyl (1.66±0.35$\mu g.kg^{-1}$). The patients were intubated with a 8 mm ID tube (Blue Line, Portex Ltd, U.K.) fitted with a lateral port arising from its distal end, allowing the measurement of the tracheal pressure through a transducer (SK model ±20, EFFA France) connected to a LEIM model 4411 amplifier. The patients were ventilated with 30% O_2 in N_2 with a Servo Ventilator 900D (Siemens Elema, Sweden) at a constant inflation flow (VT/TI) of 0.6 $l.sec^{-1}$ during 1.5 sec at 10 b.p.m.The pressure signal was recorded by a Gould TA 550 recorder. For each test breath, an end-inspiratory occlusion was performed, followed by a rapid pressure drop from a maximal pressure Pmax to an inflexion point P1 and a gradual decay to Pel. (Pmax - P1) divided by (VT/TI) provided Raw. (P1-Pel) divided by (VT/TI) gave ΔR. Raw + ΔR gave Rmax. The tidal volume divided by (Pel-PEEP) provided the static compliance Cst,rs. Control values of Raw, ΔR, Rmax, Cst,rs were recorded 6 minutes after the induction at T0(F). A 6 cmH_2O PEEP was applied. The data were recorded 6 minutes later at T1(PEEP) and PEEP was released. The first maintenance dose of fentanyl and 1 mg of atropine were given and data were recorded 6 minutes later at T2(F+A).

	T0(F)	T1(PEEP)	T2(F+A)
Cst,rs : ($ml.cmH_2O^{-1}$)	95±14.8	105.6±17.1***	92.7±13.75^{NS}
Rmax : ($H_2O.s.l^{-1}$)	5.05±0.76	5.16±1.01^{NS}	3.9 ±0.68**
Raw : ($H_2O.s.l^{-1}$)	2.01±0.44	1.84±0.73^{NS}	1.25±0.36**
ΔR : ($H_2O.s.l^{-1}$)	3.04±0.63	3.32±0.7*	2.63±0.52^{NS,a}

paired t-test to control : * $p<0.05$ ** $p<0.01$ *** $p<0.001$
^{a} : $p = 0.02$ to T1(PEEP)

PEEP induced a significant increase of ΔR as Cst,rs (i.e lung volume) increased. Consequently, the effect of fentanyl on ΔR is due to an increase of tissular resistance to flow rather to a bronchoconstriction-related increase in pendelluft.

1 : Anesthesiology 73 : A1148, 1990

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