

Title: EVALUATION OF A SYSTEM OF BREATH-BY-BREATH ANALYSIS OF $\dot{V}O_2$ AND $\dot{V}CO_2$ IN ANESTHESIA AND INTENSIVE CARE.

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INTRODUCTION.

Several methods are reported for measurement of respiratory gas exchange. However, open-circuit methods are most suited in patients during anesthesia and intensive care. Among the latter, the mixing chamber method¹ has problems in assessing the inspired gas volume in the presence of soluble inert gases such as N₂ and N₂O. On the contrary, on-line breath-by-breath integration of both inspired and expired fractions and volumes of gases are theoretically applicable in every situation. However, there are problems as to its applicability. They are, 1) bidirectional flow measurement at changing gas fractions, 2) compensation for lag and response of gas analyzers, and 3) presence of leak. We have recently developed a system to measure oxygen uptake ($\dot{V}O_2$) and carbon dioxide output ($\dot{V}CO_2$) on a breath-by-breath basis. It consists of a hot-wire flowmeter (Minato Med. Sci., Japan), a mass spectrometer (Perkin Elmer, MGA-1100), and a micro-computer. The flowmeter senses bidirectional flow and its accuracy is $\pm 2\%$ of the calibration volume. The influences of varying concentrations of gas mixtures (N₂ in O₂, CO₂ in O₂, and N₂O in O₂) and of barometric pressure on the flow output were reported elsewhere.² Compensation for both transport delay and dynamic response of the mass spectrometer to the flow signal was reported previously.³ In the present study, the accuracy of the system was evaluated by comparing it with the gas collection method in animals during mechanical ventilation, adult human subjects during varying degrees of work-load, and adult human subjects breathing an anesthetic gas.

METHOD.

1. Three rabbits (weighing 2.5-3.5kg) and 2 dogs (7-10kg) were used as alternatives to infants and children. Rabbits were tracheotomized and dogs were orally intubated under Pentobarbital anesthesia. They were paralyzed with Pancuronium bromide and mechanically ventilated with a Harvard Animal Respirometer. Expired gas was collected via a solenoid valve (dead space 7ml) synchronized with the flow-directed output of the flowmeter to a 50-L Douglas bag. Bag volume was measured with a calibrated 2-L syringe. O₂, CO₂, and N₂ fractions were measured with the mass spectrometer. Determination of $\dot{V}O_2$ and $\dot{V}CO_2$ of the gas collection method was done by the equation; $\dot{V}O_2 = (FEN_2/FIN_2 \cdot FIO_2 - FE_{O_2}) \cdot \dot{V}E$, $\dot{V}CO_2 = FE_{CO_2} \cdot \dot{V}E$ ---1) where FI and FE are inspired and expired gas fractions, respectively, and $\dot{V}E$ is expired minute volume.
2. Thirty healthy adults were studied either at rest or during varying degrees of work-load with an ergometer. They breathed ambient air via a mask. Expired gas was collected via a solenoid valve (dead space 20ml). $\dot{V}O_2$ and $\dot{V}CO_2$ were calculated by the equation 1).
3. Seven healthy adults were studied during breathing a gas mixture (30% N₂O, 20% O₂, and 50% N₂). A known volume of the gas mixture was collected in a 150-L Douglas bag. The subject first breathed ambi-

ent air spontaneously. By switching a 3-way stopcock, he inspired the gas mixture and expired via the solenoid valve to another Douglas bag. Inspired gas volume was calculated by subtracting the volume in the inspiration bag at the end of the study from the initial bag volume. $\dot{V}O_2$ and $\dot{V}CO_2$ were calculated by the equation;

$$\dot{V}O_2 = FIO_2 \cdot \dot{V}I - FE_{O_2} \cdot \dot{V}E, \dot{V}CO_2 = FE_{CO_2} \cdot \dot{V}E - FICO_2 \cdot \dot{V}I \text{ ---2)}$$

Breath-by-breath data of $\dot{V}O_2$ and $\dot{V}CO_2$ were integrated for 50 breaths and compared with those simultaneously obtained by the gas collection method.

Informed consent was obtained for all subjects and the protocol was approved by the institution.

RESULTS (Table).

An excellent linear correlation was obtained between the two methods for the animal study in the range of 10 to 70ml/min of $\dot{V}O_2$ and $\dot{V}CO_2$. In human adult subjects breathing either air or 30% N₂O, we also obtained an excellent linear correlation between the two methods.

DISCUSSION.

Most of the problems related to the open-circuit, breath-by-breath analysis of respiratory gas exchange were satisfactorily solved in the present system and we obtained excellent correlations between the system and the gas collection method in small animals during mechanical ventilation, and in human subjects breathing spontaneously either air or N₂O. We consider that the system is suited for the accurate, and continuous monitoring of respiratory gas exchange from infant to adult during mechanical ventilation, anesthesia, and exercise.

REFERENCES.

1. Heneghan CPH, Gillbe CE, Branthwaite MA: Measurement of metabolic gas exchange during anaesthesia. Br J Anaesth 53:73-76, 1981
2. Yoshiya I, Shimada Y, Tanaka K: Evaluation of a hot-wire respiratory flowmeter for clinical applicability. J Appl Physiol 47:1131-1135, 1979
3. Noguchi H, Ogushi Y, Yoshiya I, et al: Breath-by-breath $\dot{V}CO_2$ and $\dot{V}O_2$ require compensation for transport delay and dynamic response. J Appl Physiol 52: 79-84, 1982

TABLE.

	y=	b+	ax	r	range (ml)
Animal Study $\dot{V}O_2$	y=-1.1+1.1x			0.995	10-70
(air) $\dot{V}CO_2$	y=-0.8+1.0x			0.993	
Human Study $\dot{V}O_2$	y= 0.5+1.0x			0.999	150-2200
(air) $\dot{V}CO_2$	y=-0.3+1.0x			0.998	
Human Study $\dot{V}O_2$	y= 2.6+0.9x			0.947	210-370
(N ₂ O) $\dot{V}CO_2$	y=31.6+0.9x				

x: gas collection method, y: breath-by-breath method

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