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TITLE: REBREATHING DUE TO INCOMPETENT UNIDIRECTIONAL VALVES IN THE CIRCLE ABSORBER SYSTEM

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The semi-closed circle absorber anesthesia system employs individual inhalation and exhalation unidirectional check valves to guide the flow of gas within the circuit and prevent CO_2 rebreathing. The most common malfunction in these unidirectional check valves is one in which the valve disc fails to close. Information is lacking about the difference in degree of rebreathing between incompetent inhalation and exhalation valves in a circle absorber system. Accordingly, the present investigation was designed to study effect of incompetent unidirectional valves on the rebreathing of CO_2 in the semi-closed circle absorber system during spontaneous and mechanical ventilation.

An Ohmeda 8000 anesthesia machine with a semi-closed circle absorber system was used for the study. Informed consents were obtained from ten adult volunteers (**Series 1**; spontaneous ventilation). Each was allowed to breath 100% oxygen, by tight-fitting mask with a fresh gas flow (FGF) of 1 L/min. Inspired CO_2 fraction ($FiCO_2$) was recorded by mass spectrometry at the Y-connector of the breathing circuit. After a clinical steady state was achieved, measurements were obtained after 2 and 10 minutes, under the four conditions: 1) intact unidirectional valves; 2) removal of inhalation valve disc; 3) removal of exhalation valve disc; and 4) removal of both valve discs. This procedure was repeated with FGF of 3, 5, and 10 L/min. After investigational review approval and informed consent, a similar protocol was employed in five isoflurane anesthetized, paralyzed, and mechanically ventilated patients undergoing a variety of elective general, orthopedic, or gynecologic procedures (**Series 2**; controlled ventilation). Valve incompetency was once again mimicked by removal of the inhalation, exhalation, and both valve discs. Measurements were recorded after 2 minutes at 1, 3, and 5 L/min FGF. To clarify the mechanism by which rebreathing occurs, flow-volume loops (spirometry via pneumotach) were obtained in a second group of spontaneously breathing volunteers (**Series 3**; n = 5). The flow transducer was alternately interposed in the inhalation and exhalation limbs and recordings were obtained during each of the four conditions.

Removal of the inhalation valve disc alone caused minimal rebreathing ($FiCO_2$ < 1%) during both spontaneous and controlled ventilation, regardless of FGF (Table). Removal of the exhalation valve disc resulted in greater rebreathing ($FiCO_2$ > 2.4%) during both spontaneous and controlled ventilation at all FGF's. Removal of both valves yielded results similar to the removal of the exhalation valve disc alone. Bidirectional flow patterns, in the absence of a functioning check valve, were confirmed by flow-volume loops.

		SPONTANEOUS VENTILATION† $FICO_2$			CONTROLLED VENTILATION† $FICO_2$	
FGF	Valve	Control	2 min	10 min	Control	2 min
1L	Inhal	0.1±0.1	0.6±0.3*	0.3±0.1	0.0±0.0	0.3±0.4
	Exhal	0.2±0.2	3.4±0.4*	3.6±0.3*	0.0±0.0	3.1±0.5*
3L	Inhal	0.2±0.1	0.6±0.2*		0.0±0.1	0.2±0.3
	Exhal	0.2±0.1	2.6±0.5*		0.0±0.0	3.6±0.5*
5L	Inhal	0.2±0.1	0.5±0.2*	0.4±0.1	0.0±0.0	0.3±0.3
	Exhal	0.1±0.1	2.7±0.5*	2.8±0.5*	0.0±0.0	5.5±0.5*
10L	Inhal	0.2±0.1	0.3±0.1	0.3±0.1		
	Exhal	0.2±0.2	2.4±0.4	2.5±0.6*		

† data shown as mean ± standard deviation
* Statistically significance from control by paired t-test ($p < 0.05$)

Although incompetence of either check valve resulted in rebreathing of CO_2, the degree of rebreathing was dramatically different. The substantial degree of rebreathing observed in the absence of a functioning exhalation check valve is most probably due to direct rebreathing of exhaled gases from the reservoir bag (or ventilator bellows during controlled ventilation) via the exhalation limb, thus bypassing the absorber. Similar results for both spontaneous and controlled ventilation reflects the functional similarity of both systems. Increasing FGF (from 1 to 3, 5, and 10 L/min) only slightly reduced the degree of rebreathing. These results emphasize the importance of inspection and periodic maintenance of anesthesia equipment and the need for continuous CO_2 monitoring during anesthesia.

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Title: **The Effects of Trendelenburg Position and Valsalva Maneuver on the Cross-sectional Area of the Internal Jugular Vein.**

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Introduction: Cannulation of the internal jugular vein (IJV) is generally attempted with the patient in the Trendelenburg position. When puncture is initially unsuccessful, steeper Trendelenburg position or the Valsalva maneuver are generally applied in an attempt to further distend the IJV. However, the relative efficacy of these techniques has never been investigated.

Methods: We studied 16 awake unanesthetized healthy adult volunteers with approval from our Committee on Human Research. The study was divided into two parts. In part one, we studied 10 subjects in 5° and 10° of Trendelenburg, choosing a maximum of 10° of Trendelenburg because it was the steepest inclination that could be applied without the subject sliding out of position. In part two, we studied six healthy adults and examined the effect of Valsalva maneuver in a 5° Trendelenburg position. Subjects simulated a Valsalva maneuver by blowing into a plastic tube connected to a manometer, sustaining 30 cm of water pressure for 5 seconds. We used a linear array 7.5 MHz ultrasound transducer (Diasonics, Milpitas, CA) to image a short-axis view of the IJV at the level of the cricoid. Cross-sectional areas were measured off line from recordings digitized with a phantom-calibrated computerized video analysis system (Cine View, Freeland Medical Division, Indianapolis, IN).

Results: IJV cross-sectional area was not notably increased by increasing Trendelenburg from 5° to 10° (Fig.). However, the addition of the Valsalva maneuver in a position of 5° of Trendelenburg increased the mean cross-sectional area (Fig.) by 0.5 cm^2, from 2.16 cm^2 to 2.66 cm^2.

Discussion: Puncture of the IJV is routinely performed in the operating room as a means of establishing access for invasive monitoring. To determine which of the two commonly used techniques for distending the IJV was most successful, we compared the effect of Trendelenburg and Valsalva. In awake, unanesthetized volunteers, we found that performing the Valsalva maneuver in 5° of Trendelenburg distended the IJV on average more than steeper Trendelenburg position.

Conclusion: Our preliminary findings suggest that the Valsalva maneuver may be more effective than increasing Trendelenburg, when initial puncture of the IJV is unsuccessful.