be utilized as a one way air valve for endotracheal tube cuffs.

The Venovalve has a female end which fits a standard syringe for air injection and a male end which permits an air tight seal to a female needle hub. This valve comes connected to a length of intravenous tubing which can easily be removed, leaving the valve intact. As shown in the figure the valve is easily utilized as an air valve. Pressure is released simply by disconnecting the valve from the needle hub. The system is air tight and has been immersed in water for several hours without signs of minute air leaks. Clinically it has been used for prolonged endotracheal intubations without loss of pressure. This valve is inexpensive, disposable, has no parts to misplace, is quite light, and has become an excellent replacement for the bulky hemostat or clamp.

A Simple Ventilometer

JEROME H. MODELL, M.D., HERBERT SWARZ, FRANK MOYA, M.D.*

Although measurement of minute volume, tidal volume, and maximum voluntary ventilation have frequently been reported as screening tests of pulmonary function, these determinations have heretofore required the use of specialized equipment. These devices are usually both costly and somewhat fragile. In order to obviate these two objections a simple, inexpensive ventilometer has been constructed from equipment which is available even in the most remote community hospital.

The components of this ventilometer are as follows: an anesthesia mask, a 90-degree mask elbow, a nonrebreathing valve, 20 and 4-inch rebreathing hoses, a universal adapter with side arm, a 15 mm. male-male adapter, a 5-liter rebreathing bag, a hemostat, a 3-inch plastic suction tube, a small syringe and needle containing 0.2-0.5 ml. of water, a clock or wrist watch with a second hand, and a roll of tape. The parts of the ventilometer are assembled as shown in figure 1.

* Department of Anesthesiology, University of Miami School of Medicine, Jackson Memorial Hospital, Miami, Florida.

The basic principle of the ventilometer is that once its capacity is known, the patient's minute volume can be calculated as a function of the time necessary to fill the system. The capacity of the unit is that volume of gas necessary to exert sufficient pressure to displace 0.2 ml. of water in a plastic manometer open to the atmosphere.

Calibration. The respirometer is assembled without the mask and is connected directly to the delivery hose of an anesthesia machine. The Rotameter is preferred for calibration because of its inherent accuracy (± 2 per cent error). With the rebreathing bag collapsed, two flowmeters on the anesthesia machine are adjusted so that the total flow is 15 liters per minute. At zero time, the open end of the Y tube is clamped and the rebreathing bag released. Gas is allowed to flow into the rebreathing bag and when the pressure in the system exceeds 0.5 cm. of water the water is ejected from the plastic manometer. The time to ejection is recorded in seconds. The capacity of the system is then calculated as follows:
System capacity in liters
\[
= \frac{15 \text{ liters} \times \text{time elapsed in seconds}}{60 \text{ seconds}}
\]

Method of Measurement. The assembled respirometer is applied to the patient via a secure fitting anesthesia mask, a mouth piece, or cuffed endotracheal tube depending on the patient's facial configuration and degree of cooperation. A nose clip is recommended if a mouthpiece is used to insure flow of gas only through the mouth. With the rebreathing bag collapsed, the patient is allowed to inhale freely through the one way valve and exhale freely through the open end of the Y tube for one minute. This time period is used to accustom the patient to the apparatus. At the end of one minute the open end of the Y tube is clamped, the rebreathing bag released, and the time recorded. The patient is allowed to fill the system until water is ejected from the plastic manometer. The time to ejection is recorded and minute volume is calculated as follows:

minute volume in liters
\[
= \frac{\text{system capacity in liters} \times 60 \text{ seconds}}{\text{time to ejection in seconds}}
\]

The tidal volume is now calculated by dividing the measured minute volume by the number of respirations per minute.

In order to minimize the error resulting from variations in position of the rebreathing bag, the bag should be held either hanging freely or supported in an identical fashion both when calibrating the system and when performing patient measurements. It is not necessary to recalibrate the system between patients. Recalibration is necessary only if the fittings of the ventilometer are changed thus changing the system capacity.

Maximum voluntary ventilation may be measured in a fashion similar to the minute volume except; (1) the capacity of the system is increased by the addition of three rebreathing bags which are connected in parallel using appropriate adapters, (2) the non-rebreathing valve is replaced with two wide bore one-way valves to decrease resistance to high velocity air flow (fig. 2), and (3) the patient is prompted to maximally hyperventilate.

Clinical Evaluation. In order to evaluate the accuracy of this apparatus, a Wright ventilometer was inserted into the system. Minute volume was measured in 52 consecutive patients with the method described above. Re-

![Fig. 1. The ventilometer assembled. The component parts are: (1) anesthesia mask (2) 90-degree mask elbow (3) non-rebreathing valve (4) 20-inch rebreathing hose (5) universal adapter with side arm (6) 15-mm. male-male adapter (7) Y adapter (8) 5-liter rebreathing bag (9) 4-inch rebreathing hose (10) hemostat (11) plastic manometer and (12) syringe and needle containing fluid.](http://anesthesiology.pubs.asahq.org/pdfaccess.ashx?url=/data/journals/jasa/931627/)
Fig. 2. The maximum voluntary ventilation apparatus assembled. The inspiration valve is located at (1) and expiration valve at (2). The system is emptied by disconnecting at the exhalation valve (2) and collapsing the four rebreathing bags as demonstrated at (3). The system is then reconnected with all four rebreathing bags in the collapsed position; it is now ready for use.

Results obtained were compared to simultaneous readings taken with the Wright ventilometer at the end of the second full minute. Minute volumes below 4 liters per minute were not considered because of the inaccuracy of the Wright ventilometer at low flows. The average difference in the measurements between the two ventilometers was 6.9 per cent. All but two cases fell within one standard deviation of this value. Because of the excellent correlation in readings between these two ventilometers, the newer, more economical device is believed to be accurate and of practical value. The error to be expected is that inherent in the flowmeters on which the respirometer is calibrated.

Prior to construction of the respirometer model shown in figure 1, values recorded with earlier prototype types were compared to simultaneous Wright ventilometer measurements in 184 patients. The average error in this earlier composite group was 9.6 per cent. The increased dependability of the present model is attributed to the use of an adequate bore, competent nonrebreathing valve and a horizontal, rather than vertical, manometer which eliminates pressures significantly above atmospheric in the system.

Summary

A ventilometer constructed from inexpensive, readily available equipment is described. Its accuracy was found to be comparable to the Wright ventilometer. This simple and durable device makes the measurement of minute volume, tidal volume, and maximum voluntary ventilation available to all anesthesiologists.