

Clinical Workshop

S. G. HERSHEY, M.D., *Editor*

Evaluation of a New Electronic Spirometer

WILLIAM D. VISICK, M.D., H. BARRIE FAIRLEY, M.B., B.S.,
ROBERT F. HICKEY, M.D.

A newly marketed electronic spirometer* depends upon thermal conductivity as its sensing mechanism. The accompanying manual states that it is "ideal" for use in the Intensive Care Unit and that it can be used with anesthesia systems and in research laboratories. It is claimed to be "the most accurate and reliable spirometer available," with a linearity of ± 1 per cent and accuracy of ± 5 per cent.

The electronic spirometer (fig. 1) was developed primarily to monitor volumes of gas expired by patients being ventilated with a Bird ventilator. A heated thermistor, mounted on an adapter, fits on the exhalation port of the breathing circle and senses flow-induced heat loss. The current required to keep the thermistor at a constant temperature is converted into a signal which is proportional to flow. An integrator circuit converts the flow signal to volume on a breath-by-breath basis to obtain tidal volume and, over a 30-second period, to obtain a minute volume. A second thermistor in the probe corrects for variations in ambient temperature. A recorder output for flow and volume signals is available.

METHOD

The accuracy of volumes indicated by the electronic spirometer in response to changes in flow rate (continuous and intermittent), IPP waveform, gas composition (oxygen, air and nitrous oxide), and humidity was investigated. Bench tests were conducted with sources of continuous flow and sources of intermittent

flow, an electronic spirometer, and a spirometer standard, connected in series. Continuous flows of gas were delivered from variable-orifice flowmeters. Intermittent flows were produced by an Ohio 560 ventilator (approximate square flow wave) and a Harvard Pump (sinewave); flow rate was varied with a constant tidal volume and frequency, then minute ventilation was varied by changing tidal volumes, with flow rate and frequency maintained constant. A wedge spirometer recorded flow rates and a Tissot spirometer recorded volume. In order to evaluate the effects of gas composition, continuous flows of nitrogen, oxygen, and nitrous oxide were delivered from flowmeters and intermittent flows of room air and 100 per cent oxygen from the Ohio 560 ventilator. Humidity was varied from that of room air (approximately 50 per cent relative humidity) to fog by the addition of an ultrasonic nebulizer to the circuit. All tests were conducted at ambient temperature (23 ± 1 C) and electronic spirometer values were read from the meter by the same observer.

RESULTS

The effect on electronic spirometer accuracy of increasing continuous flow is illustrated in figure 2, line A. At a continuous flow of 5.7 l/min, the electronic spirometer registered 35 per cent high. This error decreased until, at a flow of approximately 21 l-min, the spirometer registered accurately. There were two variables at work with increasing continuous flows, increasing minute volume and increasing instantaneous flow rate. Line B of figure 2 illustrates electronic spirometer error with increasing minute volume and constant flow rate

Received from the Department of Anesthesia, University of California, Veterans Administration Hospital, San Francisco, California 94121.

* Bird Corporation, Palm Springs, California.



FIG. 1. A, Bird Electronic Spirometer. B, Thermistor Flow Detection Unit (1), mounted on expiration port of Bird expiratory valve assembly (2).

during intermittent flows; readings were again high until a minute volume of 21 l/min was reached. Flow-rate changes did not appreciably alter the error in the electronic spirometer between flows of 15 and 185 l/min, nor did flow waveform significantly affect accuracy.

Variations of humidity, from 50 per cent relative humidity to visible fog, did not alter spirometer accuracy either. The effects of varying gas composition can be seen in figure 3. Continuous-flow oxygen registered approximately 10 per cent high, nitrogen accurately, and nitrous oxide approximately 22 per cent low, at a flow of 21 l/min. The dif-

ference between oxygen and room air, with intermittent flows, was similar to the difference between oxygen and nitrogen with continuous flows.

Spirometer inaccuracy for tidal volumes was proportionate to that for minute volumes. There were similar variations due to changes in gas composition and mass of gas passing the thermistor, but no significant errors due to flow rate, flow waveform or relative humidity. However, the spirometer was grossly inaccurate at tidal volumes less than 350 ml. Readings varied widely from 100 ml to 840 ml from breath to breath during constant ventilation with tidal volumes less than 350 ml. This

FIG. 2. Accuracy of the spirometer with (A) continuous flow (air) and (B) intermittent flow (air).

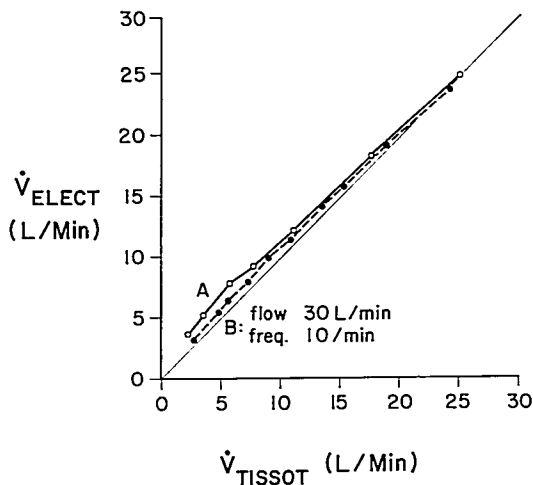


FIG. 3. Accuracy of the spirometer with continuous flows of oxygen, nitrogen and nitrous oxide.

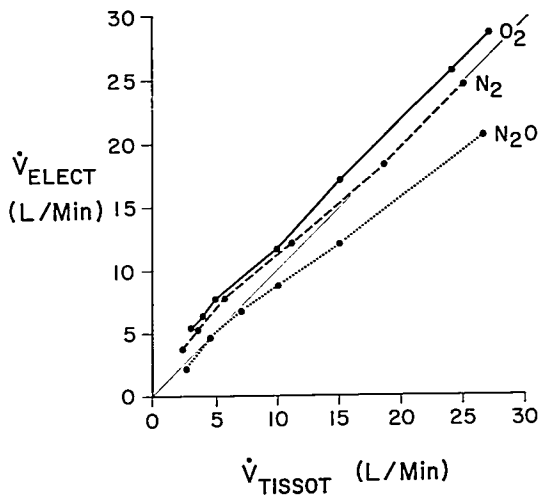


TABLE 1. Comparison of Features of the Electronic Spirometer and the Wright Respirometer

	Bird Electronic Spirometer	Wright Respirometer [†]
Accuracy determinant	Volume	Flow
Optimum accuracy	21 l/min (air), continuous or intermittent	21.5 l/min (air) continuous; 7 l/min (air) reciprocating
Low volumes	Reads high	Reads low
High volumes	Reads low	Reads high
N ₂ O measurement relative to air	Reads low	Reads high

effect was most pronounced with small tidal volumes (125 ml).

COMMENT

Of the variables tested, gas composition and minute volume affected the accuracy of the electronic spirometer the most. The instrument overread at the higher oxygen concentrations and at minute volumes less than 20 l/min. Flow rate changes in the range normally encountered with passive expiration did not appreciably alter spirometer accuracy. Humidity variations had no significant effect on spirometer accuracy. Linearity was well within the advertized limits of ± 1 per cent at minute ventilations from 0 to 30 l/min.

In view of the above findings, the electronic spirometer is considered sufficiently accurate for clinical use in Intensive Care facilities, although it is not as accurate as advertized. At minute volumes and oxygen concentrations commonly used in ICU's, it will overread. It should not be used with small children because of the errors at low minute volumes and tidal volumes.

The electronic spirometer might also be suitable for clinical use with anesthesia systems. The instrument underread 100 per cent nitrous oxide. However, the addition of oxygen to the gas mixture and the lower minute

volumes frequently encountered during anesthesia would tend to counterbalance this effect. Small tidal volumes sometimes seen during spontaneous ventilation under anesthesia might lead to grossly inaccurate tidal volume readings.

Table 1 compares features of the electronic spirometer and the Wright respirometer.† Since the errors in both are nonlinear, direct numerical comparisons are difficult. However, it should be pointed out that they are opposite in direction. Particularly significant is the difference at low volumes, at which the electronic spirometer may give a false sense of security and the Wright respirometer the reverse.

CONCLUSION

We conclude that this new electronic spirometer is sufficiently accurate for clinical use in ICU's and with conventional anesthesia systems for most adult patients. However, when particularly accurate measurements are necessary, use of the electronic spirometer requires recognition of its limitations and application of correction factors to meter readings.

REFERENCE

1. Nunn JF, Azi-Ashi TI: The accuracy of the respirometer and ventilator. *Brit J Anaesth* 34:422, 1962

† Harris Calorific, Cleveland, Ohio.