A New Disposable Spirometer

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The devices currently available for measuring vital capacity ($V_c$) and minute ventilation ($V_E$) usually suffer from one or more major deficiencies. These include: 1) cost; 2) fragility; 3) flow dependence; 4) lack of portability; 5) possibility for bacterial cross-contamination between patients. Recently, a disposable spirometer that appears to eliminate all of these deficiencies has become available.

This report assesses the accuracy and precision of this new device for measuring vital capacity and minute ventilation.

DESCRIPTION OF THE DISPOSABLE SPIROMETER

Figure 1 is a schematic diagram of the disposable spirometer. The device consists of a flexible 3-liter polyethylene bag calibrated in 25-ml increments. The bag is attached to a rigid polyethylene T tube which can be either used directly as a mouthpiece or attached to standard 15-mm anesthesia fittings.

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* Boehringer Laboratories, P.O. Box 18, Wyncote, Pennsylvania 19095. Approximate cost: $4.50 each.


METHOD OF USE

Measuring Vital Capacity. The patient breathes normally through the rigid tube while the bag entrance port is occluded with the operator's finger. On command, a maximum inhalation is taken. The operator removes his finger from the bag entrance port and occludes the exhaust end of the T tube. The patient then exhales maximally into the calibrated bag. When the exhalation is completed, the bag entrance port is again closed with the operator's finger.

To measure the exhaled volume, the device is placed on a flat surface. Using the heel of the hand, the operator displaces the volume of gas distally (away from the rigid tube) until the bag lifts upward from the surface. When this lift produces an angle of 30 degrees between the flat surface and the bag, the volume is read directly from a scale printed on the bag (fig. 2).

Measurement of Minute Ventilation. For a patient on a ventilator, $V_E$ is measured by attaching the device to the exhalation line of the ventilator and measuring the volume of three breaths. Respiratory frequency is recorded simultaneously. $V_E$ is then determined using

†When desired, supplemental oxygen can be provided through the T tube.
these two values and the nomograph printed directly on the bag (fig. 3). For $V_E$ determination in a patient breathing spontaneously, a nonrebreathing valve must be used between the patient and the spirometer to provide unidirectional gas flow into the spirometer.

**METHODS**

**Vital Capacity Measurements.** A disposable spirometer and a Wright respirometer were connected in series to a 2-liter giant syringe. Gas volumes were delivered by the giant syringe in four volume ranges (250, 500, 1,000, and 1,500 ml). Within each range, volumes were varied randomly by ±20 per cent. Flow rates varied from 3.75 l/min to 60 l/min. A total of 70 measurements was made. Two independent observers determined the volume of gas in the disposable spirometer to the nearest 25 ml using the technique previously described. These observers were unaware of the actual volume of gas delivered from the giant syringe and were unaware of each other's readings.

**Minute Ventilation Measurements.** The disposable spirometer and the Wright respirome-

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**Fig. 1.** Schematic of the disposable spirometer.

**Fig. 2.** Method of measurement using disposable spirometer.
FIG. 3. Nomograph for converting three-breath volume and respiratory rate into $V_E$. Example: A 900-ml three-breath volume with a respiratory frequency of 30 equals a $V_E$ of 9 l/min.

TABLE 1. Regression Equations and Correlation Coefficients for $V_E$ Data vs. Giant-syringe Volumes

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Regression Equation</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposable spirometer</td>
<td>$y = 0.9870X + 4.6615$</td>
<td>r = 0.9983</td>
</tr>
<tr>
<td>Wright respirometer</td>
<td>$y = 1.079X + 17.888$</td>
<td>r = 0.9901</td>
</tr>
</tbody>
</table>

TABLE 2. Regression Equations and Correlation Coefficients for $V_E$ data vs. Collins Spirometer Measurements

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Regression Equation</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposable spirometer</td>
<td>$y = 0.9215X + 0.4767$</td>
<td>r = 0.9998</td>
</tr>
<tr>
<td>Wright respirometer</td>
<td>$y = 1.1243X - 0.4980$</td>
<td>r = 0.9938</td>
</tr>
</tbody>
</table>
**Fig. 4.** Regression of disposable spirometer $V_e$ data vs. giant-syringe measurements.

\[ y = 0.9870x + 4.6615 \]
\[ r = 0.9985 \]

**Fig. 5.** Regression of disposable spirometer $V_e$ data vs. Collins spirometer measurements.

\[ y = 0.9215x + 0.4767 \]
\[ r = 0.9968 \]
ter were again connected in series and attached to the exhaust tubing of a Bennett MA-1 mechanical ventilator. Six measurements of $V_E$ were made with this system at four different delivered volumes. The output of the ventilator was calibrated before, during, and after each series of measurements using a Collins spirometer.

Results

Vital Capacity Measurements. Regression equations and correlation coefficients for the disposable spirometer $V_E$ data (one observer) and Wright respirometer $V_E$ data vs. the delivered giant-syringe volumes are presented in table 1. Figure 4 is a plot of the disposable spirometer data. There was good agreement between the two independent observers who measured the volumes of gas in the disposable spirometer (correlation coefficient = 0.998). The accuracy of the disposable spirometer compared quite favorably with that of the Wright respirometer at all delivered volumes and flow rates. Moreover, the Wright respirometer was notably flow-dependent, while the disposable spirometer was not.

Minute Ventilation Measurements. Regression equations and correlation coefficients for the disposable spirometer $V_E$ data and the Wright respirometer $V_E$ data vs. Collius spirometer measurements are presented in table 2. Figure 5 is a plot of the disposable spirometer data. Again, the results were at least as accurate with the disposable device as with the Wright respirometer.

Discussion

On the basis of the above data, it is apparent that accuracy of the disposable Boehringer spirometer is more than adequate for clinical needs. The new device has the durability to be used over the entire hospital course of any given patient. The only obvious disadvantages of the disposable spirometer are: 1) a nonbreathing valve is needed for $V_E$ determinations in a patient who is breathing spontaneously; 2) $V_E$ is not read directly but must be calculated via nomogram from three tidal volumes plus the respiratory rate. (A nomogram for calculating $V_E$ from ten tidal volumes is also available for pediatric use.) However, the cost advantages of the new device, its independence of flow rate, and its elimination of cross-contamination hazards make it an attractive clinical tool for patients who need intensive respiratory care.

Comparison of the Ventilating and Injection Bronchoscopes

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This study compares mechanical ventilation with the ventilating bronchoscope and with the injection bronchoscope during operative bronchoscopy in anesthetized, fully-relaxed patients with regard to: 1) adequacy of pulmonary ventilation; 2) pulse and blood-pressure changes; 3) time necessary for bronchoscopy; 4) acceptance by the surgeon and anesthesiologist.

Methods

Forty-two adult patients were selected for the study after having given permission for