be removed. A garden hose washer (o.d. 1 inch, i.d. ½ inch, thickness ¼ inch) is placed on the apnea control shaft (fig. 1). The knob is replaced to engage against the washer, and the Allen screw is tightened. The respiratory frequency cannot be reduced below 6 to 8 /min if spontaneous ventilation fails.

REFERENCE

A Simple Method of Measuring Oxygen Consumption in Man with Controlled Ventilation

EUGENE R. LUCIER, M.D.,* AND LEROY D. VANDAM, M.D.$

Several methods for measuring oxygen consumption in spontaneously-breathing subjects, either directly by spirometry, or indirectly by analysis of expired gases, have been described.1-3 A method for measurement of oxygen consumption with controlled respiration in the presence of anesthetic gases, utilizing the E.N.H. valve and the Engström respirator,4 has also been reported. Described herein is a simple apparatus for measurement of oxygen consumption of conscious subjects with controlled respiration.

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APPARATUS

The system consists of a 7-liter Benedict-Roth recording spirometer, a manually operated Etten ventilator, a Frumin nonbreathing valve, and carbon dioxide and water absorbers. The assemblage of the components is shown in figure 1. All valves and connections are easily made leakproof; this can be checked by occluding the patient outlet and applying pressure. With the respirator in the expanded position, the control valve opens, allowing the system to be used for spontaneous breathing. (A sponge-filled Ambu bag of fixed volume may be used in place of the Etten ventilator.) For portability the entire apparatus fits on a small cart. After each use the tubing and valves are washed and sterilized with ethylene oxide, and the carbon dioxide and water absorbers changed.
APPLICATION

The system was utilized to measure oxygen consumption of three normal subjects breathing spontaneously and five postoperative patients on Emerson volume-controlled respirators. The normal subjects’ airways were connected to the apparatus via flanged mouthpieces and the patients, via endotracheal tubes. Subjects and patients were given 100 per cent oxygen for 15 minutes prior to measurement, to accomplish nitrogen washout. Following this, the patients’ lungs were ventilated for eight to 12 minutes at the same rate and volume by the Etten ventilator on the apparatus filled with 100 per cent oxygen. The subjects breathed spontaneously for the same length of time. Oxygen consumption was measured from the slope of the spirometer tracing. A water absorber and a carbon dioxide absorber were included in the system to preclude the possibility of falsely low readings resulting from expired water vapor. Cardiac output of some patients was measured by the direct Fick principle by obtaining central venous and arterial blood oxygen tension simultaneously.

<table>
<thead>
<tr>
<th>Age (Years), Sex</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Body Surface Area (m²)</th>
<th>Oxygen Consumption*</th>
<th>Normal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Measured (ml/min)</td>
<td>1/m³/hour</td>
</tr>
<tr>
<td>Subject 1</td>
<td>28, M</td>
<td>168</td>
<td>71.5</td>
<td>1.79</td>
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<tr>
<td>Subject 2</td>
<td>31, M</td>
<td>173</td>
<td>80.7</td>
<td>1.94</td>
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<tr>
<td>Subject 3</td>
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<td>73.8</td>
<td>1.85</td>
<td>286</td>
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<tr>
<td>Patient 1</td>
<td>40, M</td>
<td>178</td>
<td>80</td>
<td>1.98</td>
<td>110</td>
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<tr>
<td>Patient 2</td>
<td>52, F</td>
<td>153</td>
<td>53</td>
<td>1.48</td>
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<tr>
<td>Patient 3</td>
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<td>72</td>
<td>1.85</td>
<td>115</td>
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<tr>
<td>Patient 4</td>
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<td>1.91</td>
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<tr>
<td>Patient 5</td>
<td>35, F</td>
<td>155</td>
<td>73</td>
<td>1.72</td>
<td>241</td>
</tr>
</tbody>
</table>

* Measurements converted to 1/m³/hour for comparison with the standard metabolic table values.¹
RESULTS

The results of measurements of oxygen consumption of three normal subjects breathing spontaneously and five postoperative patients on controlled respiration 24 hours post-thoracotomy are shown in Table 1. Both groups were supine and neither was in the basal metabolic state. The oxygen consumption in ml/min has been converted to l/m²/hour for comparison with the standard metabolic table values. The oxygen consumption values for the normal subjects are slightly higher than the standard values, probably because of their non-basal metabolic state. The patients’ oxygen consumption measurements are both above and below the standard values; variables that affect these measurements include spontaneous muscular activity, body temperature, and levels of sedation and analgesia.

Because this apparatus is a high-pressure system when used with controlled respiration, leakage is the major source of error. Each of the patients in this study had an oroendotracheal airway which allowed a tight seal. Leakage in the apparatus was easily detected and checked, as described above. On repeated measurement of the same patients’ oxygen consumption, deviation from the mean was found to lie within ±5 per cent.

DISCUSSION

The system described offers a simple, reliable means of measuring oxygen consumption in awake subjects with controlled respiration. Also, it may be used for measurements during anesthesia by filling it with the anesthetic mixture of gases when the subject has reached a stable plane of anesthesia.

The apparatus was found to be useful in evaluating patients for weaning from respirator-supported ventilation. The apparatus itself gives measurements of tidal volume, minute ventilation, oxygen consumption on controlled ventilation, vital capacity, and inspiratory force (by momentarily occluding the ventilator inlet tube with the outlet valve open) with spontaneous ventilation. By simultaneous measurements of arterial and central venous blood oxygen tensions, cardiac output and the A-aDO₂ may be measured.

REFERENCES


CASE REPORTS

Unexplained Failure of a Continuous Spinal Anesthetic

RICHARD B. WEISKOPF, M.D.

Occasionally anesthesiologists witness lack of adequate spinal anesthesia following administration of a single dose of local anesthetic through a needle which was thought to be properly placed into the subarachnoid space. Reports of lack of spinal anesthesia following administration of a local anesthetic through a catheter placed in the subarachnoid space are rare. This paper reports two such failures occurring on separate occasions in the same patient.

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