A NEW METHOD OF DEPICTING RESISTANCE OF INHALATION ANESTHETIC EQUIPMENT

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The resistance to the passage of gases offered by anesthetic equipment has been the subject of much discussion and writing. It has appeared to us that present discussions of this subject are inadequate in two ways: (1) the statement that resistance is \( X \text{ cm. of water per} \ Y \text{ liters flow} \) probably does not convey an accurate picture to the average practitioner of anesthesiology; and (2) this statement does not represent the total effect resulting from the changing resistance due to increasing and decreasing rates of flow during each breath. Actual measurement of the resistance of this equipment is quite difficult. One cannot measure its effect upon patients’ ventilation because the patient changes respiratory effort with varying resistances. Measurement of these changes in effort is difficult and unreliable. It is therefore the purpose of this study to present a means of expressing resistance in anesthetic equipment as reduction in ventilation and alteration in respiratory pattern occurring under the circumstances of a constant respiratory effort. In addition, a graphic representation of this effect on respiration is presented in the pneumotachographic record.

METHOD

The trachea of a dog was intubated under Nembutal® narcosis with a large caliber endotracheal catheter and an air-tight fit was obtained. The phrenic nerve was isolated in the left thorax and the nerve electrode of the Sanborn Electrophrenic Respirator was connected to it. The chest was closed and air was aspirated from the thorax. A pneumotachograph screen was attached to the endotracheal tube for measuring air flows and airway pressure readings were made using an electronanometer connected through a needle inserted into the airway. Recordings were made with a direct-writing recorder.

By this means it was possible to have respiratory effort constant in rate, pattern, and intensity, which is reproducible. Any changes occurring in the volume and pattern of ventilation are then the results of the resistances introduced into the air flow. Various types of anesthetic appliances which were taken directly from use in the operating room and which clinically appeared to offer no undue resistance were then connected to the apparatus in sequence and recordings were made.

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Fig. 1. Representative record of respiratory volumes and airway pressures occurring with constant effort respiration and various anesthetic equipment.

of the pattern and volume of gas flow and changes in airway pressure. These recordings were compared with those obtained with no apparatus connected and with complete obstruction to the movement of gas. Planimeter readings were made of the area under the inspiratory volume curves and the inspiratory pressure curves.

The area under three inspiratory curves of the pneumotachograph was measured four times, and the sum obtained was used as the measure of ventilation. The same method was used in measuring pressure changes. Only inspiratory curves were measured since inspiration is the active phase of respiration in this experiment and greater flow rates and pressure changes occurred in this phase. Figures obtained for various types of anesthetic equipment were compared with the controls and the probability determined by the paired "t" test.

RESULTS

The results are depicted in figures 1, 2, and 3, and in table 1. The graphic representation in figure 1 shows a reduction in ventilation oc-
currying with the to-and-fro absorber introduced into the airway and a greater reduction in ventilation when the circle absorbers were used. Figure 2 shows the effect of dirty valves and the increased ventilation occurring when these valves (mushroom type) were cleaned and dusted with Biosorb®. The statistical significance of the reduction in ventilation from the control value is indicated by the probability values in Table 1. The inverse relationship between resistance and ventilation is apparent in Figure 3.

Examination of the pattern of respiration as shown by the pneumotachograph reveals the smooth pattern of gas flow in the control which represents unimpeded gas flow. The pattern seen with the to-and-fro

<table>
<thead>
<tr>
<th>Control</th>
<th>Ventilation</th>
<th>Airway Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>To &amp; Fro</td>
<td>9</td>
<td>±2.15</td>
</tr>
<tr>
<td>Circle A</td>
<td>33.12</td>
<td>±14.3</td>
</tr>
<tr>
<td>B</td>
<td>26.25</td>
<td>±9.0</td>
</tr>
<tr>
<td>C</td>
<td>66.0</td>
<td>±9.8</td>
</tr>
<tr>
<td>C'</td>
<td>13.37</td>
<td>±14.5</td>
</tr>
<tr>
<td>D</td>
<td>21.75</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Ventilation was measured on inspiration and calculated as mean decrease in volume by the paired “t” method. Airway pressure was determined on inspiration and calculated as deviation from maximum reduction of pressure occurring with completely occluded airway.
system is quite similar. The pattern with the circle absorber shows the alterations in flow produced by the various obstacles to flow that are met, namely valves, tubing and angles. All of the tracings recorded with the circle absorbers show sharp breaks in the flow rate occurring at the beginning of both phases of the respiratory cycle which represent the opening of valves. Circle B has a characteristic low and flat expiratory curve indicating a high degree of resistance. With this circle absorber, expired gas travels through two obtuse angles and two right angles in addition to the valves, tubing and soda lime.

Discussion

In this study no attempt was made to quantitate resistance in numerical units. Airway pressures recorded simultaneously with the pneumotachograph served to relate volume changes to resistance changes. An attempt was made, however, to provide a more graphic representation of the untoward effects of resistance. In addition, it is felt that this method of study takes into account the dynamic factor involved in respiration in contradistinction to static determinations such as resistance under conditions of fixed gas flow rates. Since the factor of patient compensation was eliminated in this study, it must be emphasized that a patient breathing through Circle C, for example, may maintain adequate ventilation but does so only by significantly increased effort. It also must be emphasized that in the debilitated patient or in the patient depressed by drugs, the ability to compensate by effort is restricted and inadequate ventilation will result.

Summary

A new method of depicting the resistance to respiration in anesthetic apparatus by evaluating its impact on ventilation occurring with constant effort respiration is described.

This method provides a graphic representation of the effects of resistance. It also reveals that much of our apparatus in clinical use has resistance which significantly increases respiratory effort or decreases ventilation.