Clinical and Laboratory Evaluation of an Expired Anesthetic Gas Monitor (Narko-Test)

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A halothane analyzer (Narko-Test) was shown to have a linear response to various concentrations of cyclopropane, fluoroxene, Ethane, diethyl ether, halothane and methoxyflurane. The factors necessary to convert the analyzer scale readings to the concentration of the agents were 1.3, 2.3, 1.46, 1.28, 3.80 and 0.16, respectively. Corrections for saturated water vapor at room temperature and 100 per cent N2O were both 0.3 scale units. When used as a monitor of mixed expired gas in semiclosed or closed systems, the analyzer response was a measure of the anesthetic potency of a single agent or of the combined potency of a mixture of agents. The response to each agent was proportional to its solubility in silicon rubber or brain lipids; hence, the scale units may be regarded as multiples of minimum alveolar concentration (MAC). (Key words: Analyzer (anesthetics); Cyclopropane; Diethyl ether; Fluoroxene; Halothane; Ethane; Methoxyflurane; Anesthetic solubility—silicon rubber.)

A recently developed halothane analyzer (Narko-Test)† operates on the principle of relaxation of elasticity of silicon rubber bands in the presence of halothane vapor. Although recommended for monitoring dry inspired halothane only, use of the analyzer for continuous monitoring of end-expired gas provides a more meaningful index of anesthetic depth. The analyzer responds linearly to all volatile organic anesthetics in proportion to their silicon rubber-vapor partition coefficients.

Methods

Selected concentrations of various anesthetics were delivered to the analyzer (fig. 1) from kettle vaporizers. The gas concentrations delivered were analyzed repeatedly with a hydrogen flame detector† which was calibrated against accurately prepared water and gas standards.‡ An anesthetic circuit was modified with two three-way breathing valves and two T tubes (fig. 2) to permit analysis of either inspired or expired gas concentrations during semiclosed- and closed-circuit anesthesia.

The retention times of the same anesthetics relative to the retention time of halothane on chromatographic columns of silicon or conductive rubber§ were compared with the response of the Narko-Test to each agent.¶

Results

The instrument dial readings were directly proportional to the concentrations of each agent. Since the dial reading was intended for halothane, there was a one-to-one relationship between the halothane concentration delivered (y axis, fig. 3) and the dial reading (x axis, fig. 3). The ratio of the concentration of each agent delivered to the dial reading (slope or correction factor) is shown in parenthesis following the name of the agent (i.e., the dial reading multiplied by this factor gives the concentration of the agent). The concentration of cyclopropane delivered, on the y axis, was divided by 10, so that a dial reading of 3.0 indicates a concentration of 29 per cent (3.9 × 10). Saturated water vapor (27 mm Hg at 25°C) gave a dial reading of 0.3 per cent in the absence of any anesthetic.

The Narko-Test response to each anesthetic was proportional to the anesthetic retention time on a chromatographic column of silicon rubber (table 1). However, the analyzer response was not related proportionately to the anesthetic retention time on a chromatographic column of conductive rubber.

The analyzer responses to nitrous oxide varied from 0 to 0.3 dial units between 0 and 100 per cent. Although this response was insufficient to permit accurate monitoring of nitrous oxide, corrections were necessary when nitrous oxide was used with other agents.

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‡ Received from the Department of Anesthesiology, University of Chicago, Chicago, Illinois. Supported in part by U. S. Army Medical Research and Development Command Contract DA-17-68-C-7052.
The Narko-Test analyzer has been used in the expiratory sides of closed and semiclosed anesthetic circuits in 120 anesthesiations lasting 400 hours during the past year. No attempt was made to remove condensed water vapor from the dial window. The zero adjustment was made with a 4-l/min flow of oxygen passing through the analyzer (dry gas) prior to anesthesia. Following each anesthetization, the zero reading was unaltered (±0.1 dial unit). Calibrations before, during and after this trial period remained constant. The instrument was opened for inspection before and after the trial period and no evidence of deterioration or rust was detected.§

§In a second analyzer the dial face plate buckled and blocked the indicator needle. After the face plate was fixed in place with epoxy cement, the calibration was unchanged.

Fig. 1. Schematic of the Narko-Test halothane analyzer.

Fig. 2. Circuit schematic showing stopcock and T tube arrangements for monitoring inspired and expired anesthetic vapor concentrations with the Narko-Test analyzer (A, inspired; B, expired).
During automated programmed closed-circuit halothane anesthesia, the Narko-Test was used for continuous monitoring of expired gas (Fig. 4). When corrections for exhaled water vapor were made (0.3 dial units), the corrected readings agreed closely with gas analysis by chromatography and with alveolar concentrations calculated from measured arterial blood concentrations.

Discussion

The manufacturers’ recommendation to avoid exhaled water vapor by installing the “Narko-Test” in the inspiratory circuit is contradictory to their claim for increased economy during halothane anesthesia, since the procedure recommended necessitates the use of high-flow nonrebreathing techniques. The use of inspired concentrations is a poor guide to anesthetic management, since this variable decreases continuously with time during maintenance of a constant alveolar concentration. The use of the analyzer to monitor gas concentrations delivered has no advantage once the vaporizer output has been checked. For this purpose the Narko-Test should not be regarded as a primary standard for calibration of vaporizers, since its inherent mechanical properties (Fig. 1) eventually will lead to erroneous results. On the other hand, if periodically calibrated against an efficient kettle vaporizer equipped with a thermometer and calibrated
flowmeters, the Narko-Test provides an extremely convenient means for routine checking of a large number of vaporizers. Gas standards may be prepared in cylinders or obtained commercially, or gas chromatography may be used to analyze the anesthetic concentration.6

The range of anesthetic concentrations which can be monitored by the Narko-Test varies from 0 to 39 per cent for cyclopropane to 0 to 0.5 per cent for methoxyflurane. The upper limit is frequently inadequate for inspired concentrations required for rapid induction of anesthesia but is sufficiently adequate for monitoring expired concentrations (fig. 4). The contribution of exhaled deadspace (inspired

* $V_{R}^o$ = corrected retention volume calculated from retention time ($t_r$)².

** Not recommended by the manufacturer.

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** TABLE 1. Comparison of Analyzer Responses with Rubber and Silicon Rubber Chromatographic Retention Times ($V_{R}^o$ (agent) / $V_{R}^o$ (halothane)*

<table>
<thead>
<tr>
<th></th>
<th>Rubber (1)</th>
<th>Silicon Rubber (2)</th>
<th>Narko-Test Sensitivity (3)</th>
<th>Ratio (2/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclopropane</td>
<td>18.20</td>
<td>14.80</td>
<td>13.0</td>
<td>1.14</td>
</tr>
<tr>
<td>Fluoxetine</td>
<td>6.00</td>
<td>2.70</td>
<td>2.30</td>
<td>1.17</td>
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<tr>
<td>Ethrane</td>
<td>—</td>
<td>1.58</td>
<td>1.50</td>
<td>1.25</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>2.10</td>
<td>1.50</td>
<td>1.25</td>
<td>1.20</td>
</tr>
<tr>
<td>Halothane</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>Methoxyflurane</td>
<td>0.19</td>
<td>0.19</td>
<td>0.16</td>
<td>1.18</td>
</tr>
</tbody>
</table>

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** Fig. 4. Comparison of end-expired and arterial halothane concentrations during programmed closed-circuit halothane anesthesia. (The patient was a 49-year-old woman who weighed 56.0 kg.) $V$—$V$, systolic blood pressure; $Q$, Narko-Test dial reading; $p$, arterial halothane concentration; $\bullet$—$\bullet$, liquid halothane administered. One per cent by volume of alveolar halothane is equivalent to 17.6 mg halothane/100 ml blood (y axis).
gas) to the mixed exhaled concentration (dead-space plus alveolar gas) may be minimized by using large tidal volumes at slower respiratory rates. Normally, the contribution of this factor diminishes with time as the inspired-expired concentration gradient decreases. A more representative alveolar concentration may be determined periodically, during stable anesthesia, by momentarily decreasing the concentration delivered to the existing monitored expired concentration. This procedure negates the effect of deadspace and any contribution to the true alveolar concentration resulting from release of anesthetic from the upper airway saturated with the inspired gas concentration. Under these conditions the measured expired concentration gradually decreases and may be assumed to represent closely the decline in alveolar or arterial concentration. Since this procedure always lightens anesthesia, it should be used cautiously. The response time of this instrument is approximately eight seconds.

The exception of Ethane, the solubilities of anesthetics in silicon rubber parallel their solubilities in biological lipids 4 and olive oil 19. The analyzer reading, therefore, is proportional to anesthetic potency as well as anesthetic depth. During halothane-oxygen or halothane-nitrous oxide anesthesia, the Narkotest scale reading reflects the total cumulative anesthetic concentration (CAC). For example, in the inspiratory circuit, a 1 per cent scale reading indicates 0.3 per cent water vapor and 0.7 per cent, or one minimum alveolar concentration (MAC), of halothane. A 1 per cent scale reading with halothane and 50 per cent nitrous oxide under the same conditions, indicates 0.3 per cent for water vapor, 0.15 per cent for N\textsubscript{2}O (0.46 MAC), and 0.65 per cent for halothane (0.72 MAC), or 1.18 CAC. Adequate surgical anesthesia without use of relaxants usually necessitated analyzer readings of 1.2 to 1.4, regardless of the mixture of halothane and N\textsubscript{2}O employed. When large doses of relaxants were employed with halothane or halothane and N\textsubscript{2}O, analyzer reading of 0.8 to 1.0 provided adequate analgesia (0.5 to 0.7 CAC). Mixtures of halothane, methoxyflurane and N\textsubscript{2}O were administered simultaneously to several patients, necessitating analyzer readings of 1.2 to 1.4 dial units (0.9 to 1.1 CAC). When the scale is read in MAC units instead of per cent halothane, a reading of 1 to 1.5 indicates adequate surgical anesthesia for any single agent or any mixture of volatile agents. Since the detector is non-specific and records the combined gas concentrations in proportion to their combined anesthetic potency, the dial readings should not be interpreted as a true measurement of any single agent when the rubber in the anesthetic circuit has been exposed to another agent during the preceding anesthetic procedure. When a true analysis of a single agent is desired, disposable polyethylene breathing tubes should be used. 21

References