THE "NARKOTEST" ANAESTHETIC GAS METER

D. C. WHITE AND BRIDGET WARDLEY-SMITH

SUMMARY
The Narkotest anaesthetic gas meter is capable of measuring the concentration of gaseous or volatile anaesthetic agents within the range used clinically. The principle of operation is that the relaxation produced by anaesthetic agents in lightly tensioned silicone rubber strips is transmitted to a pointer by a lever system. The instrument is calibrated by the makers for halothane 0–3% and this calibration was found to be sufficiently accurate for clinical purposes. We also calibrated the meter for a variety of other agents. The response time, effect of gas flow rate, water vapour, carbon dioxide and exposure to more than one agent were investigated. The Narkotest was considered to be a useful and versatile meter which can be connected directly into an anaesthetic circuit. Frequent correction of zero drift is necessary to maintain accuracy.

The Draeger Narkotest M anaesthetic gas meter* is a device intended for the measurement of halothane concentrations in anaesthetic circuits. It relies upon the change in physical properties of silicone rubber when exposed to halothane. Since this is an entirely non-specific effect, the meter will respond to other anaesthetics, and indeed to many other agents as well.

MATERIALS AND METHODS
The meter, as shown in figure 1, is enclosed in a robust stainless steel case measuring 16 x 10 x 4 cm and weighing 1.75 kg. The meter studied was fitted with Draeger standard tapers (internal diameters of 5.4 and 4.0 cm) and special adapters, which can be supplied by Draeger, are required for use with British machines. The scale is linear and is graduated in divisions of 0.2% halothane. The instrument must be used in a vertical position. A diagram of the interior is shown in figure 2. Gas passes over lightly tensioned silicone rubber strips which are connected to the pointer by a lever system. Anaesthetic agents are highly soluble in the silicone rubber which dissolves the agent from the gas passing over it. A change in elasticity is produced which results in a movement of the pointer. A zero adjustment control is provided on the back of the instrument. There is also a sensitivity control, but this is set by the makers and does not require adjustment.

*British Patent No. 1174491 (1969). This instrument can be obtained from Draeger Medical Ltd., 128 High Street, Edgware, Middlesex.

Fig. 1. External appearance of the Narkotest M.
The "Narkotest" Anaesthetic Gas Meter

The resistance to gas flow through the meter is extremely low, 0.1 cm H₂O at 20 l./min. The meter may, therefore, be connected directly into respiratory circuits.

The agents tested were halothane (Fluothane, ICI Ltd), nitrous oxide, cyclopropane, diethyl ether, chloroform, methoxyflurane (Penthrane, Abbott Laboratories), enflurane (2-chloro-1,1,2-trifluoroethyl difluoromethyl ether, Ethrane, Abbott Laboratories Ltd.), trichloroethylene (Trilene, ICI Ltd.), divinyl ether (Vineshene, May and Baker Ltd.), and the halothane/ether azeotrope.

Non-anaesthetic agents tested were Freon-12 (dichlorodifluoromethane), Freon-114 (1,2-dichlorotetrafluoroethane), ethanol and acetone.

The agents were delivered in known concentrations as follows, halothane from a Vapör (Draeger Medical Ltd.), methoxyflurane, chloroform and trichloroethylene from Cyprane vaporizers. Nitrous oxide and cyclopropane were delivered from calibrated Rotameters. The Freons were mixed with oxygen, and their concentrations derived from measuring the oxygen concentration of the mixture with a Servomex paramagnetic oxygen analyser. All other agents were vaporized in glass vaporizers constructed on the Copper Kettle principle (White and Dundas, 1972).

All concentrations were checked using a portable refractometer (Riken Ltd.; Hulands and Nunn, 1970). In all cases, air or oxygen was the carrier gas, neither of which affected the meter.

The meter is stated by the makers to be suitable for the measurement of halothane and is so calibrated. We therefore conducted most tests with this agent. The following points were studied: (1) Accuracy, gas flow rate and response time; (2) Effects of (a) carbon dioxide, and (b) water vapour; (3) Effect of temperature.

As stated, halothane vaporized in air was obtained from a Draeger Vapör halothane vaporizer. This instrument has been shown to be accurate over a wide range of gas flows (Hill, 1963) and our model was checked using a Rayleigh refractometer (by courtesy of Dr H. G. Epstein). The meter was mounted vertically for all tests and the zero checked and adjusted if necessary. In conducting tests of this nature it is important to use connecting tubing of impermeable material such as nylon.

We then tested the effect of various anaesthetic and other agents as enumerated above. Experiments were also performed to determine the effects of two agents acting simultaneously on the meter. Pairs of agents used were nitrous oxide and halothane, halothane and cyclopropane, methoxyflurane and cyclopropane. We also tested the halothane/ether azeotrope (66/34 v/v).

RESULTS

Accuracy, gas flow rate and response time.

The meter was found to be accurate within ±0.1% halothane at full scale deflection (3%) provided it had been recently exposed to the agent and rezeroed after a suitable wash-out with air, that is until the pointer ceased to move. If the meter had been left unused for more than about six hours it was sluggish in response and tended to read low. Following the first deflection, considerable zero error was usually observed and required correction, which was carried out with air passing through the meter. This error disappeared with repeated use over a short period.

Accuracy was not affected by the gas flows tested which lay between 1 and 12 l./min. Response time was adversely affected by very low flows, and extremely high flows could cause flutter inside the meter. For all subsequent tests a flow of 4 l./min was used. As might be expected, the direction of gas flow through the meter was immaterial.

The maximum speed of response was obtained with flow rates of 4 l./min and above and, as can be seen from figure 3, a 1% halothane reading was reached in 90 sec. The makers claim approximately 8 sec for the half value response time. The time taken for the meter to return to zero on passing air through it was about the same as that taken to reach a steady reading with anaesthetic.
Carbon dioxide.

One hundred per cent carbon dioxide produced a deflection of 0.25 and deflections produced by physiological concentrations could not be detected.

Water vapour.

The manufacturers recommend that the meter should only be used on the inspiratory side of anaesthetic equipment, nevertheless water vapour compensation in the form of a thread of water-sensitive plastic is built into the meter. When saturated water vapour at room temperature is passed through the meter, an initial deflection of 0.2 is produced which falls back to zero after a delay due to the lag in the compensating mechanism. At 37°C, which is above the recommended range of temperature, saturated water vapour gave a reading of 0.7 falling to 0.45 after 5 min.

Table I. Narkotest readings at different temperatures.

<table>
<thead>
<tr>
<th>Halothane concentration (%)</th>
<th>Scale reading at 14°C</th>
<th>37°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>2.2</td>
<td>0.8</td>
</tr>
<tr>
<td>2.0</td>
<td>2.75</td>
<td>2.25</td>
</tr>
<tr>
<td>2.5</td>
<td>2.75</td>
<td>2.25</td>
</tr>
<tr>
<td>3.0</td>
<td>2.55</td>
<td></td>
</tr>
</tbody>
</table>

Temperature.

Temperature compensation in the form of bimetallic strips is incorporated in the meter, and it is claimed by the makers to be effective between 15 and 35°C. We tested it in controlled temperature rooms at 14 and 37°C. In these extreme conditions errors developed as shown in table I. It can be seen that the meter tended to read high at low temperatures and low at high temperatures. Within the range of normal ambient temperature (19-25°C) the compensation appeared effective.

The meter responds to all inhalational anaesthetic agents. Results for these agents are shown on the "equiMAC" diagram, figure 4 (see discussion). Results for divinyl ether and trichloroethylene are shown in figure 5 as no MAC (minimum alveolar concentration) values are available to enable them to be plotted on figure 4. The response of the meter

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**Fig. 3.** Time taken to obtain steady readings for three agents chosen for their different solubilities in silicone rubber.

**Fig. 4.** Narkotest reading plotted against vols% anaesthetic concentration with the MAC value (for dog) occurring at the same point on the abscissa for each agent.

**Fig. 5.** Narkotest readings plotted against vols% for different agents.

**Abbreviations used in figs. 4, 5 and 6.**

HAL, halothane; MXF, methoxyflurane; CHCl₃, chloroform; C₅H₆, cyclopropane; ENF, enflurane; DEE, diethyl ether; N₂O, nitrous oxide; DVE, divinyl ether; AZ, halothane/ether azeotrope; TCE, trichloroethylene; ETH, ethyl alcohol; FR-12, Freon 12; FR-114, Freon 114.
was found to be linear for all these agents, but the response time varied according to the solubility of the agent in silicone rubber. This is shown in figure 3; an agent highly soluble in rubber, such as methoxyflurane, giving a slower response than a slightly soluble agent such as cyclopropane.

Results from the mixtures tested showed that in all cases the reading was equal to the sum of the same concentrations tested separately. Results from the halothane/ether azeotrope are shown in figure 6, and the line is seen to lie between those for ether and halothane in a position appropriate to the composition of the mixture. For both Freons the results were linear and are shown in figure 5. Only one value was obtained for ethanol (vapour pressure at 0°C) and this is also shown on figure 5. Acetone (vapour pressure at 0°C) produced a deflection in excess of full scale.

CLINICAL APPLICATIONS

Provided frequent reference to a standard is available, the meter is sufficiently accurate for clinical use. But when accurate temperature compensated vaporizers are available, it is hardly necessary to monitor the inspired concentration of agent. However, when a vaporizer is used inside a circle system with low gas flow, measurement of the concentration is desirable, and for this purpose the Narkotest, with its low resistance, is well suited. A further application occurs when vaporizers are used with gas flows outside their calibrated range and also when concentrations of agent below the lowest calibrated value of the vaporizer are required. This last point may be of importance when it is considered that the cumulative MAC value of 60% nitrous oxide and 0.5% halothane (commonly the lowest calibrated concentration) exceeds 1 MAC.

We have found that the meter can be satisfactorily placed either on the inspiratory or on the expiratory side of the anaesthetic apparatus. The difference between the expired and inspired concentrations provides a measure of the saturation of the patient.

DISCUSSION

In a previous review of this instrument (Lowe and Hagler, 1971) it was claimed that the meter could be used to give a direct reading of anaesthetic potency, i.e., that the MAC value for one agent would give the same scale reading as the MAC value for another agent. However, our results do not support the view that the Narkotest can be used as an “MAC meter”. To substantiate this we have plotted our results in the form shown in figure 4. In this diagram the concentrations of anaesthetic agents on the ordinate are plotted on an “equiMAC” scale where the MAC value for each agent is at the same point on the scale. The values used for MAC are those determined for the dog (Eger et al., 1969) and these are given in table II. A similar result is obtained when using human MAC values. Departure from the “MAC meter” concept is seen by the failure of the MAC value for each agent to give the same meter reading.

TABLE II. (From Eger et al., 1969).

<table>
<thead>
<tr>
<th>Agent</th>
<th>MAC (vol %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrous oxide</td>
<td>188.0</td>
</tr>
<tr>
<td>Cyclopropane</td>
<td>17.5</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>3.0</td>
</tr>
<tr>
<td>Enflurane</td>
<td>2.2</td>
</tr>
<tr>
<td>Halothane</td>
<td>0.87</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.77</td>
</tr>
<tr>
<td>Methoxyflurane</td>
<td>0.23</td>
</tr>
</tbody>
</table>

We have found that within the limits already discussed, this is an interesting and highly versatile instrument, capable of a satisfactory accuracy for clinical purposes.

ACKNOWLEDGEMENTS

We wish to thank Draeger Medical Ltd. for the loan of a Narkotest; Dr H. G. Eostein for his advice and assistance; and Miss Brenda Dobson and Miss Carolyn Hooton for their secretarial assistance.
REFERENCES


DAS "NARKOTEST" ANÄSTHESIE GASOMETER

ZUSAMMENFASSUNG


LE COMPTEUR DE GAZ ANESTHÉSIE NARKOTEST

SOMMAIRE

Le compteur de gaz anesthésique Narkotest est capable de mesurer la concentration d'agents anesthésiques gazeux ou volatiles dans les limites utilisées en clinique. Le principe de l'opération est que la relaxation produite par l'agent anesthésique dans des strips de caoutchouc siliconné sous tension légère est transmise à un marqueur par un système de leviers. L'instrument est calibré par le fabricant pour halothane 0-3 pourcent et cette calibration s'est avérée suffisamment exacte pour l'emploi clinique. Nous avons aussi calibré le compteur pour un nombre d'autres agents. Le temps de réaction, l'effet de la vitesse du flux gazeux, la vapeur d'eau, anhydride carbonique et l'exposition à plus qu'un agent ont été étudiés. Le Narkotest est considéré comme un compteur utile et versatile, qui peut être connecté directement au circuit anesthésique. Une correction fréquente de la déviation au zéro est nécessaire pour conserver l'exactitude des mesures.

EL MEDIDOR NARCOTEST DEL GAS ANESTÉSICO

RESUMEN

El medidor Narcotest de gas anestésico puede medir la concentración de agentes anestésicos gaseosos o volátiles dentro de los valores utilizados en clínica. Su principio de operación consiste en que el relajamiento producido por agentes anestésicos en tiras de goma de silicona en ligera tensión es transmitido a un indicador mediante un sistema de palanca. Este instrumento es calibrado por los fabricantes para halotano al 0-3 por ciento y se encontró que esta calibración es suficientemente exacta para las finalidades clínicas. Nosotros también hemos calibrado este medidor para otros diversos agentes. Fueron investigados el tiempo de respuesta, el efecto de la velocidad del flujo gaseoso, el vapor de agua, anhídrido carbónico y exposición a más de un agente. Se consideró que el Narcotest es un medidor útil y versátil que puede ser conectado directamente dentro del circuito del anestésico. Es necesaria una corrección frecuente de la tendencia a cero para mantener la exactitud.