BREATH-BY-BREATH HALOTHANE MONITORING DURING ANAESTHESIA

A study in children

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SUMMARY

The use of a halothane meter in routine paediatric anaesthesia with controlled ventilation is described. The results demonstrate the accuracy achieved in the control of the alveolar halothane concentration. Measurement of the alveolar halothane concentration revealed responses to surgical stimulation otherwise obscured by neuromuscular blockade, and this may indicate insufficient depth of anaesthesia.

Volatile anaesthetic agents are administered on the basis of clinical observation and pharmacological knowledge. Calibrated vaporizers provide more predictable inspired concentrations, but measurement of the expired concentration is required to provide information on the rate of uptake and alveolar concentration of the drug.

Routine measurement of the alveolar anaesthetic concentration would enable the extensive data on MAC values (Eger, 1974) to be applied, resulting in more precise control of anaesthesia. We present examples of results obtained using a rapid response meter to measure the inspired and alveolar concentrations of halothane and discuss the value of continuous breath-by-breath monitoring in clinical anaesthesia.

PATIENTS AND METHODS

Fifty fit, healthy children aged 6 months to 13 yr (weight 9-35 kg) were studied during anaesthesia for routine abdominal, urological or orthopaedic surgery. Premedication comprised either oral trimetazine tartrate 3 mg kg\(^{-1}\) 2\(\frac{1}{2}\) h before operation or papaveretum 0.4 mg kg\(^{-1}\) and hyoscine 0.06 mg kg\(^{-1}\) i.m. 1 h before operation. An i.v. infusion was established and anaesthesia was induced with thiopentone 6 mg kg\(^{-1}\) followed by pancuronium 0.1 mg kg\(^{-1}\). The trachea was intubated with a snug fitting Portex uncuffed oral endotracheal tube and controlled ventilation of the lungs commenced with either 100% oxygen or 70% nitrous oxide in oxygen using a Blease PulmoFlater with a paediatric attachment. The minute volume required to maintain \(P_{a}CO_2\) 5.3 kPa (40 mm Hg) at a respiratory rate of 14-18 b.p.m. was calculated (Nunn, 1977). Halothane was added from a Fluotec Mark 3 vaporizer either at a constant inspired concentration or by the use of "overpressure" (an initially high concentration which was reduced subsequently). Heart rate, e.g. and temperature were monitored continuously. The systolic arterial pressure was recorded regularly by indirect sphygmomanometry.

The halothane meter (Tatnall, West and Morris, 1978) was situated in the expiratory limb of the ventilator circuit close to the endotracheal tube connector (fig. 1).

FIG. 1. Schematic diagram of the anaesthetic breathing system showing the position of the halothane meter.

The inspired concentration was quantified by measurement of the concentration in the initial fraction of expired gas (deadspace gas). No ventilation/perfusion inequality was detected in any patient and the end-tidal concentration was assumed to represent the alveolar concentration (Eger and Bahlman, 1971). Utilizing the MAC value for halothane (Saidman et al., 1967) an equilibrium
alveolar concentration was calculated for each patient.

Towards the end of surgery the halothane was discontinued and the rate of decrease of alveolar concentration observed. On completion of surgery the residual neuromuscular blockade was antagonized with neostigmine 0.07 mg kg$^{-1}$ and atropine 0.02 mg kg$^{-1}$ i.v. Ventilation was continued with 100% oxygen and the tracheal tube removed when spontaneous respiration had been re-established.

RESULTS

The relatively slow increase in alveolar concentration towards equilibrium in response to a constant inspired concentration is illustrated in figure 2. The concentration achieved finally was substantially smaller than that inspired. If insufficient time was allowed before surgery commenced or if the selected inspired concentration was too small during maintenance, a decrease in the alveolar concentration from that expected was observed following surgical stimulation.

Such a response (fig. 2) occurred in four of 10 patients anaesthetized to a cumulative MAC value of 1.0 x MAC. No signs of inadequate anaesthesia, including movement, were detected in these patients. In 40 patients in whom a cumulative MAC value of 1.2 x MAC was used, this response was not observed. Figure 3 illustrates the use of "overpressure" to attain rapidly and maintain a constant alveolar concentration of 1% halothane.

Figure 4 illustrates the precise control of the alveolar concentration which was possible by applying

![Figure 2](image2.png)

**FIG. 2.** Decrease in alveolar halothane concentration in response to surgical stimulation. Patient: 7 yr, 25 kg. Operation: inguinal herniotomy. Minute volume: 3.8 litre min$^{-1}$; nitrous oxide and halothane.

![Figure 3](image3.png)

**FIG. 3.** Inspired concentration "overpressure" using large decremental steps to attain a constant alveolar concentration of 1.0% halothane. Patient: 5 yr, 26 kg. Operation: soft tissue release right foot. Minute volume: 3.8 litre min$^{-1}$; oxygen and halothane.

![Figure 4](image4.png)

**FIG. 4.** Application of alveolar concentration "overpressure". Patient: 11 yr, 28 kg. Operation: inguinal herniotomy. Minute volume: 4.0 litre min$^{-1}$; nitrous oxide and halothane.
small decremental adjustments in the inspired concentration. In this patient a greater alveolar concentration was sustained initially before reduction to that required for maintenance; this technique could be described as "alveolar overpressure".

Figure 5 demonstrates the different rates of decrease in alveolar concentration when halothane was discontinued in three patients (of comparable weight) in whom anaesthesia had been maintained at a constant alveolar concentration of 0.6% for 12.5, 30.5 and 610 min respectively. The time taken for the alveolar concentration to decrease by 75% was 2.5, 6.5 and 19.5 min respectively.

**DISCUSSION**

Using a constant vaporizer setting many factors including variation in vaporizer output (Adams, 1977), the constituent materials, capacity and type of anesthetic breathing system (Eger, Larson and Severinghaus, 1962), the second gas effect (Epstein et al., 1964) and patient variability, influence both the inspired concentration and the trajectory of the alveolar concentration curve.

The problem of estimating the complex dynamic relationship between vaporizer setting and alveolar concentration is eliminated by the use of breath-by-breath measurement and this enables the safe use of "overpressure" to attain the required alveolar concentration. The time constants involved in the relationship between the alveolar and brain halothane concentrations (Mapleson, 1973) may be used as a guide in the use of "alveolar overpressure" (the logical extension of inspired "overpressure") to accelerate the transition to the required brain concentration during induction of anaesthesia.

The concept of MAC provides the anaesthetist with definable objectives regarding the alveolar concentration appropriate for satisfactory anaesthesia in 50% of patients. Recently an expanded MAC, calculated to encompass 95% of patients, has been reported (de-Jong and Eger, 1975), thus extending the usefulness of this index. For example, MAC for halothane in adults is 0.74% whilst the expanded MAC$_{95}$ is 0.90% or 1.2 × MAC. Thus, by taking into account the variation of MAC with age (Gregory, Eger and Munson, 1969) and the MAC fractions of all the components of the anaesthetic sequence (Saidman and Eger, 1964), the equilibrium alveolar halothane concentration required to anaesthetize 95% of all patients may be determined.

The reduction in alveolar concentration associated with surgical stimulation during induction and maintenance of anaesthesia may be explained by an increase in cardiac output since ventilation was controlled and factors which would significantly alter the mixed venous anaesthetic concentration (for example a blood transfusion) were not applicable. Stimulation of the peritoneum was more likely to produce this response than was cutting the skin, the standard for MAC evaluation in man.

It has been suggested that the cardiovascular responses from autonomic activity during surgery may be considered as part of a general stress syndrome (Savidge, DuBois and Holly, 1978). The results obtained from four of the patients anaesthetized to 1.0 × MAC may be interpreted as indicating insufficient depth of anaesthesia.

Following withdrawal of inhalation agents, the rate of decrease of alveolar concentration has been used to define recovery (Stoelting and Eger, 1969), and the patient's ability to respond to verbal commands and maintain his own airway is related to the alveolar concentration (Stoelting, Longnecker and Eger, 1970). Continuous observation of the alveolar halothane concentration during this stage of anaesthesia enables the anaesthetist to recognize the time at which recovery can be expected to occur and is of particular value following long anaesthetics where increased body saturation has occurred.

Measurement of depth of anaesthesia is vague and correlates poorly with clinical signs (Cullen et al., 1972), especially if neuromuscular blocking agents
have been administered, thus denying information available from respiratory parameters and movement in response to surgery. Routine measurement of the arterial blood anaesthetic concentration is impractical, but when using inhalation agents instantaneous measurement of the alveolar concentration may be readily performed. This has the advantage of being non-invasive and causes minimal interference with surgery.

It is clear that breath-by-breath monitoring is useful for other techniques of anaesthesia, including spontaneous ventilation and the use of the closed circuit. These applications are the subject of further study.

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REFERENCES


SURVEILLANCE DE L’HALOTHANE SOUFFLE PAR SOUFFLE PENDANT L’ANESTHESIE

Etude effectuée sur des enfants

RESUME

L’usage d’un doseur d’halothane pour les anesthésies pédiatiques routinières avec ventilation contrôlée est décrit dans cet article. Les résultats obtenus démontrent que l’on a pu arriver à une bonne précision dans le contrôle de la concentration alvéolaire d’halothane. Les mesures de la concentration alvéolaire d’halothane ont révélé des réactions à la stimulation chirurgicale qui étaient jusqu’ici cachées par le blocage neuromusculaire, ce qui peut indiquer une insuffisance de la profondeur de l’anesthésie.

HALOTHANÜBERWACHUNG DES ATEMS WÄHRENDE DER NARKOSE:
EINE STUDIE BEI KINDERN

ZUSAMMENFASSUNG


CONTROL ALIENTO POR ALIENTO DEL HALOTANO DURANTE LA ANESTESIA

Un estudio en los niños

SUMARIO

Se describe el uso de un medidor de halotano en anestesia pediátrica rutinaria con ventilación controlada. Los resul-tados demuestran la exactitud lograda en el control de la concentración alveolar de halotano. La medición de la concentración alveolar de halotano reveló respuestas a la estimulación quirúrgica que, de otra manera, hubieran estado oscurecidas por el bloqueo neuromuscular, lo que puede indicar una intensidad insuficiente de la anestesia.