HALOTHANE ADSORPTION COMPLICATING THE USE OF SODA-LIME TO HUMIDIFY ANAESTHETIC GASES

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SUMMARY

If the anaesthetic circle system is arranged to increase the humidity of fresh anaesthetic gases by placing the carbon dioxide absorbent canister between the fresh gas inlet and the patient, drying of the soda-lime can occur. Very dry soda-lime adsorbs significant quantities of halothane. Using fresh soda-lime, effluent halothane concentration reached 50% of the input concentration in 35 s, but this time increased to 500 s when dry soda-lime was used. The use of dry soda-lime can result in a slow inhalation induction or in the release of adsorbed halothane during a subsequent anaesthetic.

Adequate humidification of inspired gas has been recognized as a significant problem in clinical anaesthesia (Spalding, 1956; Burton, 1962), especially with paediatric patients (Rackow and Salanitre, 1969). A common solution is to add a humidifier to the fresh gas line or to the inspiratory limb of the circle. Dery and others (1967) and Berry and Hughes-Davies (1972) described a paediatric anaesthesia circuit which delivered from the soda-lime itself 80% relative humidity at 24 °C. They achieved this by placing the soda-lime canister between the source of fresh gas and the patient, allowing the dry gas to take up water from the absorbent. No serious problems have been reported using this arrangement.

Using a similar circle (fig. 1, right), we noted that occasionally the induction of anaesthesia with halothane was markedly prolonged. We suspected this was caused by adsorption of halothane on to the soda-lime. Eger, Larson and Severinghaus (1962), using fresh soda-lime (15% water by weight), showed that for halothane the soda-lime/air partition coefficient is about 1, suggesting that halothane uptake is negligible. However, Titel and others (1968) and Lowe, Titel and Hagler (1971) reported that halothane is taken up by soda-lime as an inverse function of the water content of soda-lime. If the soda-lime is used to humidify fresh gas, then the soda-lime must dry, allowing halothane to be adsorbed. We investigated whether the use of this anaesthesia circle configuration could produce sufficient drying of the soda-lime to result in a clinically significant adsorption of halothane.

METHODS

Drying of soda-lime and distribution of remaining water. Four twin-compartment absorbent canisters were each filled with 2.3 kg of fresh soda-lime (Sodasorb, W. R. Grace and Co., confirmed 14–16% water by weight, 4–8 mesh). They were placed in the anaesthesia circle as shown in figure 1 (right), and exposed to a flow of dry oxygen 5 litre min⁻¹ for 30 or 40 h. The fractional water content of the soda-lime in two canisters was then determined by calculating the change in weight produced by drying them for 3 h in a 120 °C kiln. The distribution of water within a canister was determined by studying six 50-g samples of soda-lime from various sites within the upper (proximal) and the lower (distal) compartments of each of the remaining two canisters. The water content of each sample was determined as above.

Adsorption of halothane by soda-lime. The adsorption of halothane by soda-lime was studied by measuring changes in halothane concentration at a point between the outlet of the canister and the rubber breathing hose in the paediatric circle described above. A 5-litre min⁻¹ flow of 1% halothane was introduced to the circle via the fresh gas inlet. No known absorbent, such as rubber, was used in the apparatus. The soda-lime had been pretreated by passing through it a 5-litre min⁻¹ flow for 0–40 h...
of (a) dry oxygen, (b) oxygen saturated with water vapour at ambient temperature or (c) dry oxygen for 40 h and then, for an additional 40 h, a 5-litres min\(^{-1}\) flow of oxygen saturated with water vapour at 37 °C. Halothane concentration was measured using an infra-red analyser (Beckman LB-2) calibrated at four points with halothane standards (Matheson Gas Products) and recorded on a polygraph (Offner). The time required for the effluent halothane concentration to reach 50% of the fresh gas concentration was determined from the polygraph trace and termed \(t_{50}\) (fig. 2). When effluent halothane concentration was greater than 95% of the halothane concentration at the fresh gas inlet, halothane input was discontinued and the adsorbed halothane was washed out by continuing the 5-litre min\(^{-1}\) flow of dry oxygen.

**Halothane adsorption by "clinical" soda-lime.** Canisters of soda-lime were collected from three circuits where the anaesthetists reported that an inhalation induction was markedly prolonged, and stored in double polythene bags. All patient records were analysed for other potential sources of prolongation, such as difficulty in airway management, inadequate flows or low halothane concentrations. Previous usage of these canisters of soda-lime was unknown. In each case, adsorbed halothane was washed out for a minimum of 10 min until no effluent halothane could be detected when oxygen was passed through the circle. \(t_{50}\) was determined and the washout curve plotted for each specimen, as in the previous experiment.

**RESULTS**

**Drying of soda-lime and distribution of remaining water.** The water content of the soda-lime exposed to dry oxygen for 30 h was 9.0% while that of the soda-lime exposed for 40 h was 6.8%. The water contents of 50-g samples of soda-lime were variable. After exposure to dry oxygen 5-litre min\(^{-1}\) for 30 h, the water contents in the proximal canister ranged from 3 to 5% while that of the distal canister ranged from 9 to 11%. After 40 h exposure, the water contents ranged from 0.1 to 4% and 7 to 11%,
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Adsorption of halothane by soda-lime. Figure 2 is representative of the sigmoid-shaped curve of the effluent halothane concentration plotted against time. $t_{50}$ values for different soda-lime pretreatment programmes are plotted in figure 3. Fresh soda-lime not exposed to drying gas, had a mean $t_{50}$ of 38 s (range 33–40 s). $t_{50}$ increased linearly with duration of exposure to dry oxygen ($r = 0.97$), reaching 500 s after 40 h of drying (range 430–525 s). Soda-lime treated with humidified oxygen for 40 h, with or without pretreatment with dry gas, had the same $t_{50}$ as fresh soda-lime. The washout curve was also found to be sigmoid and is illustrated in figure 2. Washout of fresh soda-lime to 0.05% effluent halothane required a mean washout time of 88 s (range 80–95 s). Soda-lime exposed to dry oxygen for 40 h had a mean washout time of 1250 s (range 1100–1600 s). Washout time for soda-lime exposed to humidified oxygen, or which was exposed to dry and then humidified oxygen was the same as for fresh soda-lime.

Halothane adsorption by “clinical” soda-lime. $t_{50}$ values of soda-lime from circuits where an inhalation induction had been markedly prolonged averaged 450 s, with a range of 345–650 s. The washout time to 0.05% effluent halothane concentration averaged 1050 s (range 900–1300 s). The adsorption–washout plot had the same sigmoid shape as that found in experiments with dry soda-lime.

DISCUSSION

The use of dry gas during anaesthesia has been associated with V/Q abnormalities and increased microatelectasis (Rashad et al., 1976), loss of body heat (Roe, Santulli and Blair, 1966; Rashad and Benson, 1967), abnormalities of ciliary morphology and function (Chalon, Loew and Malebranche, 1972), and an increase in viscosity of mucus, crust formation and obstruction of the respiratory tree or endotracheal tube (Spalding, 1956). To avoid these problems, fresh gases are usually passed through a humidifier before delivery to the patient. Humidifiers, however, are an added expense, take up important space around paediatric patients, and have hazards of their own (Egan, 1973).

Since Déry and others (1967) and Berry and Hughes-Davies (1972) described the use of soda-lime as a humidifier by passing fresh gas first through the canister before delivery to the patient, an elegant and inexpensive technique has been available for clinical use. An improvement in this circle is described by Chalon, Simon and others (1978) who recently constructed a circle which uses not only the water of the soda-lime but also the heat of reaction from the canister to maximize humidification. A disposable canister circuit is also commercially available (Disp CO2 Sorb, Dryden Corporation) which uses the humidification capacity of soda-lime (Weeks, 1975).

Few disadvantages have been attributed to such circles (fig. 1, right). When gas composition is altered, a minor lag time may be expected as the void space is washed out (Schreiber, 1972). Chalon (1974) has pointed out the possibility of bacterial growth on a warm, moist inspiratory valve, which may also cause valve malfunction. It has also been suggested that additional modifications of the circle may be desirable to augment humidification further (Ramanathan, Chalon and Turndorf, 1976; Chalon, Patel et al., 1978; Chalon, Simon et al., 1978). However, in this study we have demonstrated a major deficiency. We have shown: (1) exposure of soda-lime to a flow of dry gas results in drying of the soda-lime; (2) the soda-lime in the proximal canister becomes relatively dry when that in the distal canister still contains large amounts of water. Thus, clinically significant quantities of halothane can be...
adsorbed. This occurs at a time when the effluent gas continues to be well-humidified (Salanitre, E., personal communication); (3) halothane adsorption increases with drying time; (4) adsorbed halothane can subsequently be slowly released; (5) soda-lime recovered from three circuits where induction was unexpectedly prolonged was later found to absorb large amounts of halothane.

Soda-lime in this anaesthesia circuit dries under two common clinical conditions. When a patient is disconnected from the circle, and the flow of gas through the circle is inadvertently continued, drying will occur. If the flow is not stopped at the end of the working day, a significant drying will have occurred by morning, producing in the soda-lime the capacity to adsorb a clinically significant quantity of halothane. Drying will also occur when the flow of fresh gas greatly exceeds minute ventilation, although it is doubtful whether this often leads to a clinically significant change.

Clinical problems can follow the use of dry soda-lime. Since \( t_w \) increases about 10 s for each hour of exposure to dry gases, an inhalation induction can be markedly slowed, leading to a prolonged excitement phase. A patient who is anaesthetized using an anaesthesia circle containing soda-lime that has adsorbed halothane will receive this agent as it is being washed out from the soda-lime by fresh gas. This presents a potential danger to a patient for whom halothane is contraindicated. A patient at risk from malignant hyperpyrexia is probably not sufficiently protected from halothane exposure by changing only the rubber components of the circle (Eger, Larson and Severinghaus, 1962); the soda-lime must be changed as well.

Despite these problems, a circuit which utilizes the water content of soda-lime to humidify anaesthetic gases is useful in paediatric anaesthesia. However, it may be advantageous to modify the circuit so that, during induction, fresh gas enters the inspiratory limb after the canister, thus delivering a known halothane concentration directly to the patient. Once a suitable depth of anaesthesia is attained, the source of the fresh gas can be switched to a site before the canister, allowing humidification of the fresh gas for the duration of the anaesthetic.

REFERENCES

Berry, F. A. Jr, and Hughes-Davies, D. I. (1972) Methods of increasing the humidity and temperature of the inspired gases in the infant circle system. *Anesthesiology*, 37, 456


**BRITISH JOURNAL OF ANAESTHESIA**

**ADSORPTION D'HALOTHANE COMPLIQUANT L'UTILISATION DE CHAUX SODEE POUR HUMIDIFIER LES GAZ ANESTHESIQUES**

**RESUME**

Si le circuit anesthésique est conçu pour augmenter l'humidité des gaz anesthésiques frais en plaçant la boîte absorbant le dioxyde de carbone entre l'arrivée des gaz frais et le patient, il peut s'ensuivre un asseclement de la chaux sodée. La chaux sodée très sèche adsorbe des quantités significatives d'halothane. Si l'on utilise de la chaux sodée fraîche, la concentration d'halothane à la sortie du canister atteint 50% de la concentration à l'entrée en 35 s, mais ce temps s'allonge jusqu'à 500 s lorsqu'on utilise de la chaux sodée sèche. L'utilisation de chaux sodée sèche
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peut entraîner un allongement du temps d'induction par inhalation ou le relargage de l'halothane adsorbé au cours d'une anesthésie ultérieure.

DURCH BINDUNG VON HALOTHAN AUFTRETENDE KOMPLIKATION BEI DER BENUTZUNG VON ABSORBERKALK SUR ANFEUCHTUNG DER NARKOSEGASE

ZUSAMMENFASSUNG

COMPLICACION DEL USO DE LA CALIZA SODICA PARA HUMIDIFICAR LOS GASES ANESTÉSICOS COMO CONSECUENCIA DE LA ABSORCIÓN DE HALOTANO

SUMARIO
Si el sistema del ciclo anestésico se dispone para aumentar la humedad de gases anestésicos puros, colocando el filtro absorbente de dióxido de carbono entre la entrada de gas puro y el paciente, puede llegar a secarse la caliza sódica. Cuando ésta está muy seca absorbe cantidades importantes de halotano. Haciendo uso de caliza sódica pura, la concentración de halotano de salida alcanzó el 50% de la concentración de entrada en 35 s, pero este tiempo llegó a ser de 500 s cuando se usó caliza sódica seca. El usar caliza sódica seca puede traer como consecuencia una lenta inducción de aspiración o la liberación de halotano absorbido durante una anestesia posterior.