ERRORS IN OXYGEN TENSION MEASUREMENTS CAUSED BY HALOTHANE

J. G. DENT AND K. J. NETTER

Summary

Halothane, independent of oxygen tension, increased the signal of the gold/silver-silver chloride microelectrode. The output of microelectrodes at different oxygen tensions in the presence of increasing amounts of halothane has been measured. Halothane causes an increase in the electrode signal which is proportional to its concentration. This effect results from the polarographic reduction of halothane. It is concluded that the gold/silver-silver chloride microelectrode cannot be used to measure oxygen tension during halothane anaesthesia.

A gold/silver-silver chloride microelectrode system has been developed by Erdmann, Kunke and Krell (1972) for measuring oxygen tension in micro-areas of living tissue during anaesthesia and has been used also to measure oxygen tension in actively metabolizing liver microsomal preparations (Wolf et al., 1975). We observed that the addition of halothane to a solution increased the apparent oxygen tension. This phenomenon has been investigated to determine its cause and to assess the magnitude of the halothane effect.

Methods

Electrodes were prepared by the method of Erdmann (1972) and were coated with a hydrophilic resin (Primal Ac-35 Doduco KG, Pforzheim, West Germany). The electrode signal was amplified with a model 1200 Chemical Microsensor (Transidyne General Corp. Michigan, U.S.A.) and the microsensor output was recorded on a chart recorder. Measurements of oxygen tension were made at 37 °C in a 1-cm square spectrophotometer cuvette. Halothane 2.5% v/v in dimethylformamide (DMF) was added to 2 ml of sample solution, usually 0.9% w/v sodium chloride. It was established that up to 200 µl DMF gave no signal with the electrode. Solutions of known oxygen tension were prepared by bubbling 0.9% sodium chloride with 10% oxygen and 90% nitrogen, compressed air (20.8% oxygen), and pure nitrogen. The addition of a small amount of glucose and glucose oxidase ensured the maintenance of anaerobic conditions.

Results

Increasing amounts of halothane added to the saline solutions resulted in an increase in the electrode signal (fig. 1). The effects of halothane were independent of the initial oxygen concentration. Similar results were obtained in other assay media (1.15% potassium chloride and diluted guineapig blood) and when halothane was added as a solution in ethanol.

Fig. 1. The influence of halothane at different concentrations on the response of a single electrode. Measurements were made with a single electrode in two separate experiments, and . Halothane was added as a 2.5% v/v solution to 0.9% sodium chloride. Halothane concentration (mg/100 ml) was calculated from the specific gravity of halothane (1.87 g/ml at 20 °C). Solutions of different oxygen tension were prepared as described in the text.

J. G. DENT, B.SC, PH.D.; K. J. NETTER, DR.MED.; Department of Pharmacology, Section of Toxicology, University of Mainz, Obere Zahlbacher Str. 67, D-65 Mainz, Germany.
It may be concluded that the increased electrode signal did not result from a halothane–solvent or halothane–assay medium interaction. Commercially available halothane has thymol (0.01% w/v) present as a stabilizing agent; however, thymol in large quantities (100 mg/100 ml) did not affect the electrode signal.

As halothane is a highly volatile liquid, the possibility of its evaporation from the saline solution was investigated by adding halothane to saline at a concentration of 10 mg/100 ml. The electrode current was recorded immediately and remained constant for 30 min. This was taken to indicate the stability of halothane in saline, when added in DMF. If the effects of halothane were on the silver/silver chloride reference electrode its effect would not be important in anaesthesia as the reference electrode is frequently a surface electrode applied to the skin. However, by separating the gold and silver/silver chloride electrodes in two saline solutions joined by a simple salt bridge, it was shown that the increased signal occurred only when halothane was added to the solution containing the gold electrode.

Different electrodes exhibited different sensitivities to halothane. This effect might be the result of different thicknesses of the hydrophilic coating. Measurements of the signal produced by halothane on electrodes which had not been coated with the hydrophilic resin revealed that uncoated electrodes were more sensitive but equally variable in their response to halothane. However, the response of a given electrode decreased following coating. The response of coated electrodes varied from 30 to 140 mm Hg apparent oxygen tension per 10 mg halothane per 100 ml saline. These variable factors make it impossible to devise a universally applicable correction factor.

The fact that halothane affects the electrode signal and that this effect is located at the cathode suggested that halothane was being reduced polarographically. The polarization profile for oxygen and halothane is shown in figure 2. It is apparent that the profiles overlap and that it is not possible to distinguish between halothane and oxygen by an alteration in the electrode polarizing potential. The plateaux for the first reductive step of oxygen and that for halothane overlap substantially.

Halothane in the gas phase caused an increase in the signal from a conventional Clark-type electrode fitted with a 25-μm thick polyethylene membrane (Severinghaus et al., 1971). It was also reported that halothane sensitized the electrode to oxygen. We were unable to demonstrate an effect of halothane on a Clark electrode (L. Eschweiler & Co., Kiel) fitted with a 12-μm thick polytetrafluoroethylene (PTFE) membrane when halothane was added at a concentration of 500 mg/100 ml saline. However, at higher halothane concentrations (1500 mg/100 ml) or in the absence of the membrane, an increase in electrode current was observed. These results indicate that the Clark-type electrode fitted with a PTFE membrane may be used to measure oxygen tension in the presence of halothane concentrations in the clinical range.

We found that halothane did not have a sensitizing effect on the gold microelectrode. Furthermore, the observation that the coating of gold microelectrodes with hydrophilic resin decreased the sensitivity to halothane indicates the possibility that the discovery of a coating material permeable to oxygen but impermeable to halothane may allow oxygen measurements with the microelectrode in the presence of halothane.

**DISCUSSION**

The results described here indicate that measurement of oxygen tension with the gold/silver–silver chloride electrode during halothane anaesthesia is...
likely to be inaccurate. The blood halothane concentrations associated with clinical anaesthesia are stated as being between 9 and 22.5 mg/100 ml (Atallah and Geddes, 1972). With the electrode used to obtain the data in figure 1, such concentrations of halothane would increase the apparent \( P_2 \) by 60–150 mm Hg. Thus the error is very large. The fact that halothane is reduced polarographically indicates the possibility of developing a polarographic method for the determination of halothane in biological fluids. This is being investigated currently.

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REFERENCES


ERREURS DANS LES MESURES DE LA TENSION D'OXYGÈNE CAUSES PAR L'HALOTHANE

RESUME

L'halothane augmente, indépendamment de la tension d'oxygène, le signal de la microélectrode or/argent-chlorure d'argent. On a mesuré la production des microélectrodes à différentes tensions d'oxygène en présence de quantités croissantes d'halothane. L'halothane provoque dans le signal de l'électrode une augmentation qui est proportionnelle à sa concentration. Cet effet provient de la réduction polarographique de l'halothane. On en conclut que l'on ne peut pas utiliser les microélectrodes or/argent-chlorure d'argent pour mesurer la tension de l'oxygène pendant les anesthésies obtenues par l'halothane.
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