Laboratory Report

Halothane Mimics Oxygen in Oxygen Microelectrodes

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The effects of halothane and enflurane on the polarographic measurement of oxygen with five platinum and three gold microelectrodes were examined. Oxygen microelectrodes were calibrated in saline solution equilibrated with either nitrogen (N₂) or air, then either halothane, 1.0 per cent, or enfurane, 2.0 per cent, was added to the gas mixture. For each electrode, polarographic curves were determined during exposure to five equilibrating gas mixtures: N₂, air, N₂ plus halothane, air plus halothane, and N₂ plus enfurane. Halothane variably increased the current produced (and therefore the estimated oxygen tension) at all polarizing voltages in saline solution equilibrated with either N₂ or air. The effect was present in both conical platinum electrodes and recessed-tip gold electrodes and was not prevented by membrane coatings of polystyrol, Rhoplex or collodion. Enflurane did not alter the polarographic measurement of oxygen. It is concluded that tissue oxygen tension measurements, made with these microelectrodes and membranes, may be unreliable in the presence of halothane. (Key words: Anesthetics, volatile: enfurane; halothane. Measurement techniques: microelectrodes, oxygen. Oxygen: tension.)

Platinum or gold microelectrodes with tip diameters of 2–5 μm are used to measure tissue oxygen tension (P₉₀) under various physiologic conditions. Their small size and shape allow them to be inserted into tissues with minimal distortion and permit the measurement of tissue oxygen tension, which typically is lower than arterial or venous values. The technique is based on the reduction of oxygen at the cathodic microelectrode tip, which generates a current proportional to the oxygen tension in the medium surrounding the tip. At the electrode tip, oxygen diffuses to the polarized active surface, where it is reduced and H₂O is formed, with H₂O₂ being an active intermediate. The release of electrons from the oxygen generates a small current, which can be measured with a sensitive ammeter. Since the measurement depends on the reduction of a substance at the electrode tip, it is possible that other compounds could be reduced and generate a current as well.

Severinghaus et al. reported the polarographic reduction of halothane and several other halogenated hydrocarbons in the standard Clark-type oxygen macroelectrode, which resulted in an upward drift of the PO₂ reading. Dent and Netter reported a similar effect of halothane on the Erdmann-type gold/silver–silver chloride microelectrode and suggested that different electrode membranes might minimize this effect. We have examined the effects of halothane and enfurane on the platinum oxygen microelectrode and the gold, recessed-tip, oxygen microelectrode with three different membrane materials.

Materials and Methods

Five conical, platinum-in-glass, polystyrol-coated, oxygen microelectrodes were prepared as described by Silver. Both an oxygen electrode and a silver–silver chloride reference electrode were placed in a thermally-controlled, transparent, glass chamber containing 0.9 per cent saline solution at 37 C. Calibrating gases were bubbled into the saline solution through a fritted disc at the bottom of the chamber. The electrodes were polarized at 0.1-volt increments from 0.2 to 1.0 volts negative, relative to the reference electrode. The resultant current was measured with a sensitive picammeter, and polarograms (current vs. voltage) were constructed. For each electrode, polarograms were determined for saline solution equilibrated with each of five gases: nitrogen (N₂) alone; halothane, 1 per cent, in N₂; enfurane, 2 per cent, in N₂; air alone; halothane, 1 per cent, in air. The volatile anesthetics were delivered by standard anesthetic vaporizers and the delivered anesthetic concentrations were determined by gas chromatography.

Three gold, recessed-tip oxygen microelectrodes as described by Whalen et al. were coated with collodion, Rhoplex, or polystyrol and were tested in 0.9 per cent saline solution at 37 C. Current was measured at a constant polarizing voltage of −0.7 volts during each

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Received from the Department of Anesthesiology, University of Virginia Medical Center, Charlottesville, Virginia 22908. Accepted for publication April 25, 1978. Supported in part by grants HL17091 and Research Career Development Award 5K04 HL00837 from the NIH, Bethesda, Maryland.

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0003-3029/79/1000/0047 $00.65 © The American Society of Anesthesiologists, Inc.
of the following conditions: N₂ alone; halothane, 1 per cent, in N₂; halothane, 1 per cent, in air; air alone; enflurane, 2 per cent, in N₂; enflurane, 2 per cent, in air.

Results

Figure 1 depicts the polarograms for a typical platinum microelectrode. In saline solution equilibrated with N₂ alone (zero Pₒ₂), the current was negligible relative to the air current at all voltages tested. Enflurane did not alter the zero current from that seen with N₂ alone. In contrast to enflurane, halothane markedly increased both the zero current and the air current. Similar effects were present with all five platinum microelectrodes, although the magnitude of the halothane effect was unique for each electrode. For example, at a polarizing voltage of −0.7 volts the halothane-produced increases in the N₂ current ranged from 171 to 13,900 per cent, while the air current was increased 35 to 400 per cent.

When recessed-tip gold oxygen microelectrodes were polarized at −0.7 volts under the conditions described, halothane, 1 per cent, increased the current, whether in N₂ or air, with membranes of polystyrol, Rhoplex, or collodion. Again, enflurane, 2 per cent, in N₂ or air, had no effect on the recessed-tip electrode.

Discussion

These data indicate that the measurement of Pₒ₂ by either the conical platinum electrode or the recessed-tip gold microelectrode may be unreliable in the presence of halothane. Dent suggested that various membranes might eliminate this effect, but the polystyrol, collodion and Rhoplex membrane coatings used here were unable to prevent the halothane effect. Severinghaus et al. suggested that a polarizing voltage of approximately −0.5 volts might minimize this effect in the Clark-type oxygen electrode, and the polarogram shown here is generally supportive of this concept. However, other polarograms showed no consistent relationship between the polarizing voltage and the halothane effect. Since the magnitudes of the halothane effect were inconsistent among the different microelectrodes, it was not possible to remedy the problem with a single polarizing voltage or with a correction factor that applied to all electrodes. Although Bates et al., using an in-vivo oxygen macroelectrode, found no significant effect of halothane at Pₒ₂'s greater than 105 torr, the microelectrodes used here were affected by halothane at Pₒ₂ values from zero to 157 torr.

In contrast to halothane, enflurane had no effect on the polarographic measurement of oxygen by microelectrodes. Perhaps halothane, a brominated hydrocarbon, is much more easily reduced at the microelectrode tip than is enflurane, which is a chlorinated ether. It should be emphasized that the oxygen microelectrode measures an oxidation-reduction reaction and not simply Pₒ₂. Any compound that is significantly reduced at the electrode tip will mimic oxygen.

At the present time, clinical use of tissue oxygen microelectrodes, such as for evaluating muscle ischemia, is not common in the United States, although it is more so in Europe. The implications for their use in the presence of halothane are obvious. Our results indicate that the measured "oxygen" current will be variably increased by clinical concentrations of halothane, resulting in grossly overestimated tissue oxygen tensions.

In summary, we tested two types of oxygen microelectrodes and three membrane materials in the presence of halothane, enflurane, and no anesthetic. Halothane, but not enflurane, produced major alterations in the polarographic measurement of oxygen, independent of the type of electrode or membrane material. Although halothane always increased the measured current (and thus the apparent "oxygen" tension), the effect was variable among electrodes, so
that no universal polarizing voltage or correction factor could be applied to correct for the halothane effect.

The authors gratefully acknowledge the assistance of Brian R. Duling, Ph.D., in testing the gold recessed-tip microelectrodes, and Mr. Nguyen in the preparation of the platinum microelectrodes.

References