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Investigation of Electrochemical Carbon Monoxide Sensor Monitoring of Anesthetic Gas Mixtures

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AN electrochemical sensor has previously been reported to provide useful detection of carbon monoxide while exposed to one minimum alveolar concentration of volatile anesthetics.[1] My independent laboratory study yields further evidence supporting the possible utility of electrochemical carbon monoxide sensor measurements in anesthetic gas mixtures.

Several scientific investigations have elucidated the chemistry of base-catalyzed volatile anesthetic degradation into by-products, including carbon monoxide.[2–4] Multiple case reports corroborate the laboratory studies with clinical documentation of significantly elevated intraoperative carboxyhemoglobin levels as a consequence of anesthetic circuit carbon monoxide contamination.[5–7] Only a single case report exists of the suspected correlation between intraoperative carbon monoxide exposure and actual patient morbidity.[8] However, veterinary anesthetic practice may also utilize volatile anesthetic agents in the presence of alkaline carbon dioxide absorbents. Voluntary reporting *via* the United States Pharmacopeial Convention Veterinary Practitioners Reporting Program recorded a signal clustering (three dogs) of perioperative animal deaths with routine anesthetics/surgeries associated with intraoperative carbon monoxide exposure involving isoflurane and soda lime/Baralyme® (Chemetron Medical Division, Allied Healthcare Products, St. Louis, MO).[9]

Current anesthesia monitors provide only indirect evidence of carbon monoxide production in anesthesia circuits.[10–12] Early specific carbon monoxide identification in anesthetic gases could avert patient exposure to that toxic by-product. My *in vitro* investigation assesses the capability of an electrochemical carbon monoxide sensor in various anesthetic atmospheres with maximal volatile anesthetic concentrations.

Materials and Methods

All carbon monoxide measurements were made at 18.6–23.2°C and one atmosphere using the Bacharach Snifit Model 50 electrochemical carbon monoxide sensor (Bacharach Inc., New Kensington, PA) with a range of 0–1,999 parts per million (ppm) certified for use in 15 to 90% relative humidity (noncondensing). Gas samples were studied with relative humidity ranging from 0 to 52%. Instrument carbon monoxide measurements on 20 samples were obtained for each study atmosphere before and after carbon monoxide addition.

Each of five volatile anesthetic agents (halothane, enflurane, isoflurane, desflurane, and sevoflurane) was tested at the highest possible standard vaporizer delivery concentration in the presence and absence of nitrous oxide (45–64%). The experimental gas test chamber consisted simply of a hard plastic housing for the electrochemical sensor electrode with chrome-plated connecting pipes and plastic stopcocks for gas removal/insertion fitted to borosilicate glass syringes at either end. Certified standard-grade 1.048% carbon monoxide in balance nitrogen was added to the test chamber in quantities verified by room air control trials to result in carbon monoxide concentrations of 38.5 ppm and 385 ppm.

To test the functional resiliency of this electrochemical sensor to complex by-product mixtures, carbon monoxide measurements were also made on a desflurane atmosphere decomposed by dried Sodasorb® (W.R. Grace, Chicago, IL). The decomposition process created a by-product mixture containing carbon monoxide, and samples of that mixture were diluted with air to result in an electrochemical sensor indication of approximately 500 ppm. By-product interference with sensor function was tested by an enrichment technique wherein an aliquot of each sample was removed and exchanged with a certified standard grade carbon monoxide additive sufficient to approximately double the sensor reading. In addition, atmospheres of carbon dioxide (6.38%), oxygen (96.3% and 99.6%), and nitrous oxide (31.9%, 72.2%, and 96.3%) were evaluated by the sensor.

Two-tailed Student *t* test statistical analysis was employed using the 0.01 significance level.

Results

Several volatile anesthetic atmospheres were associated with a statistically significant difference between the mean sensor measurement and the theoretical carbon monoxide level. In all cases except those involving nitrous oxide, however, the observed measurement values did not deviate more than 2% from theoretical values. Hence, none of the volatile agents created any clinically significant instrument bias (fig. 1).

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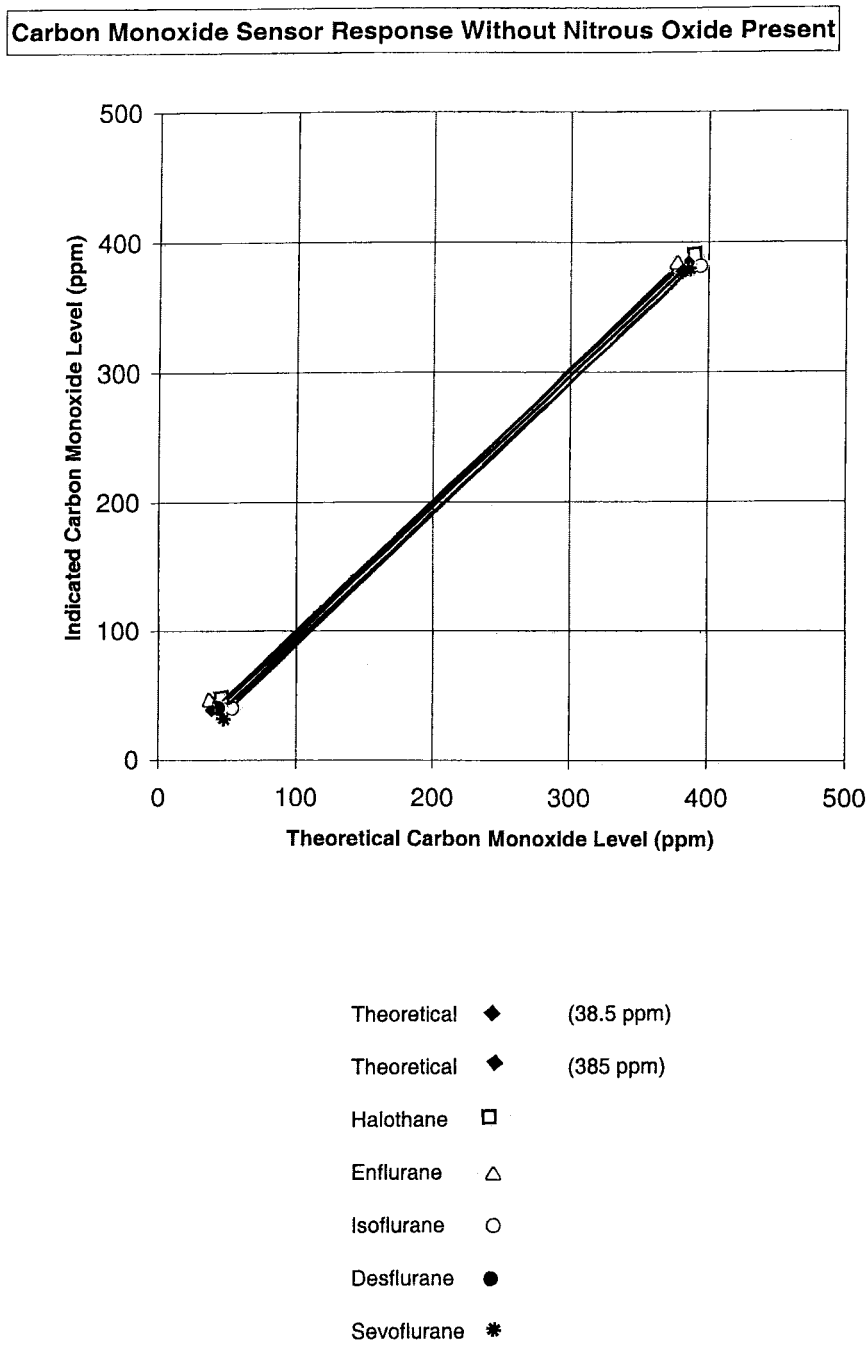

Fig. 1. Two-point sensor calibration line derivations for low (38.5-ppm) and high (385-ppm) carbon monoxide concentration without nitrous oxide present. All volatile anesthetics (halothane, enflurane, isoflurane, desflurane, and sevoflurane) form calibration points virtually superimposed on the room air control results.

Nitrous oxide atmospheres were associated with a statistically significant negative deflection of the sensor readings from theoretical values (fig. 2). Underestimation of actual carbon monoxide level by approximately 13% was determined for atmospheres containing 60% nitrous oxide using this sensor. Nitrous oxide presence also slightly decreased the electrochemical sensor zero (−1 to −2 ppm).

Oxygen (96.3% and 99.6%) caused negative deflection of the room air zero (−3 to −5 ppm) yet minimal effect (less than 2% instrument measurement bias) on the mean carbon monoxide level determinations. Carbon dioxide (6.38%) did not appreciably affect the room air zero or the sensor carbon monoxide measurements.

Detection of 98% of the carbon monoxide enrichment additive to degraded desflurane by-product mixtures demonstrated that the sensor was virtually free of by-product interference as measured by that technique.

Discussion

Previous research and reports affirm that inadvertent carbon monoxide generation by volatile anesthetic degradation is indeed a real albeit rare problem.[5–9] The

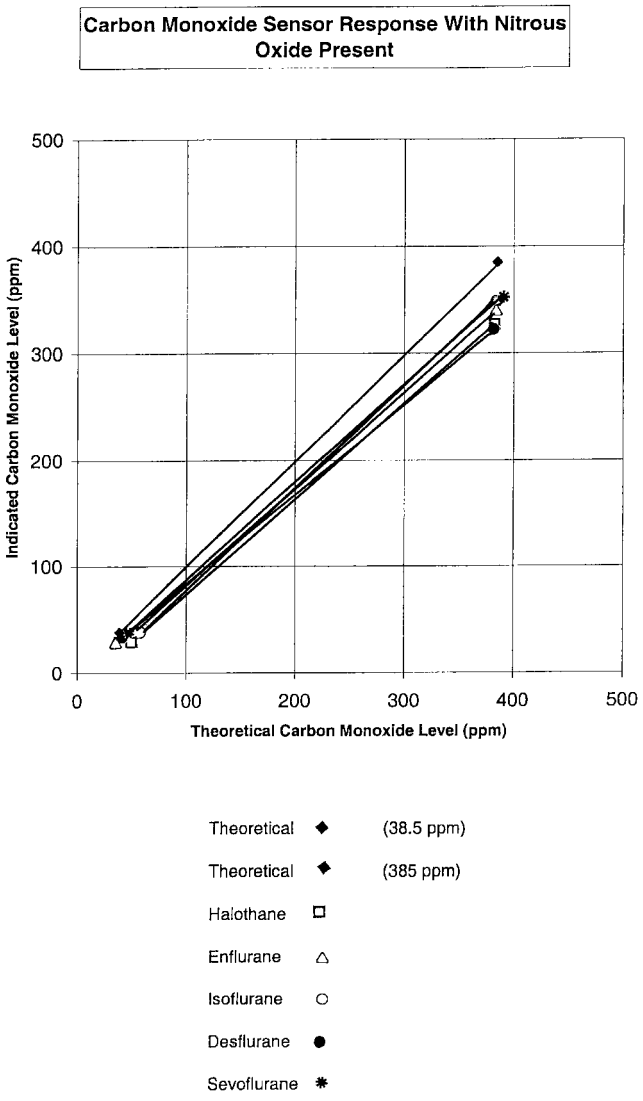

Fig. 2. Two-point sensor calibration line derivations for low (38.5-ppm) and high (385-ppm) carbon monoxide concentrations with nitrous oxide present. All volatile anesthetics (halothane, enflurane, isoflurane, desflurane, and sevoflurane) with nitrous oxide concentrations (45–64%) demonstrate negative deflection of the calibration points from room air control results. The average negative instrument bias approximated 13% for a nitrous oxide concentration of 60%.

findings of high carboxyhemoglobin levels in patients and significant carbon monoxide contamination in anesthesia circuits are startling realities that should heighten anesthesia practitioner awareness and vigilance for this insidious poison.

The results of this study further validate the ability of an electrochemical carbon monoxide sensor to detect carbon monoxide appropriately within a clinically useful range while exposed to the highest volatile anesthetic concentrations attainable in an anesthesia circuit. In addition, the electrochemical sensor properly measured carbon monoxide concentrations during exposure to a complex gas mixture of base-decomposed desflurane and attendant by-products. A concentration-dependent negative instrument bias effect of nitrous oxide on the electrochemical sensor carbon monoxide readings is described, which, although interesting, still allows sensitive detection of clinically significant carbon monoxide in the anesthesia circuit. Because carbon monoxide possesses manifold toxicity mechanisms and may be quickly poisonous even to healthy adults, protection of patients from such a contaminant is an obvious imperative.

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