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Laboratory Note

Correction Factors for Nitrous Oxide in the Infrared Analysis of Carbon Dioxide

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The magnitude of errors due to spectral overlap and collision broadening by nitrous oxide in the infrared analysis of carbon dioxide were separately determined in a group of Godart Capnographs. Errors caused by spectral overlap ranged from 0.08 to 0.7 per cent apparent CO_2 when 70 per cent N_2O was analyzed. These were sufficiently variable to necessitate determination by each investigator for his own equipment. Errors resulting from collision broadening were less than 0.5 per cent apparent CO_2 when 5 per cent CO_2 was analyzed with 70 per cent N_2O as the background gas. These errors were not sufficiently variable to necessitate individual determination. Machine age was not significantly correlated with the magnitude of error due to either effect. (Key words: Collision broadening; Spectral overlap; Capnographs.)

IT HAS BEEN SHOWN that nitrous oxide produces errors in the infrared analysis of carbon dioxide owing to overlapping of their infrared absorption spectra and to collision or "pressure" broadening of the CO_2 absorption[1-7] spectrum. A discussion of the theory of the origin of these errors and practical techniques for their measurement and correction is provided by Hill and Powell.[5] Most authors have tried to incorporate both corrections in a single factor. Only Bergman and Powell[1,4] make clear their attempts to measure separately the correction factors for spectral overlap and collision broadening. All investigators but one studied Beckman and Liston-Becker equipment. Smith *et al.*[7] investigated only a single Godart Capnograph. They clearly distinguished errors resulting from spectral overlap from those caused by collision broadening, but reported correction data for collision broadening errors only. For these reasons we separately determined the correction factors for spectral overlap and collision broadening in a group of seven Godart Capnographs.§

Materials and Methods

Seven Godart Capnographs, ranging in age from two to seven years, were studied. Calibrating gas mixtures were generated from Wösthoff mixing pumps. Two Wösthoff mixing pumps were connected in series so that the second pump was supplied with a known mixture of N_2O and O_2 which could be diluted with a known amount of CO_2. Mixtures were verified to 0.1 per cent v/v by Scholander analysis. Capnograph outputs were recorded on a Texas Instruments servowriter whose linearity had previously been verified with measured voltage inputs.

All Capnographs were subjected to three experiments. First, calibration mixtures of CO_2 and O_2 were measured to check the analyzer's linearity. Second, 0 to 100 per cent N_2O in O_2 was supplied in 10 per cent increments to determine the correction factor for spectral overlap. Last, the magnitude of the pressure broadening correction was determined. The spectral overlap correction was made by zeroing the analyzer on the nitrous oxide concentration of interest, and various concentrations of CO_2 were measured in that percentage N_2O. Concentrations of 1 to 10 per cent CO_2 were measured in 50, 70, and 80 per cent N_2O.

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§ Godart Capnograph. Available from Instrumentation Associates, Inc., 17 West 60th Street, New York, New York 10023.

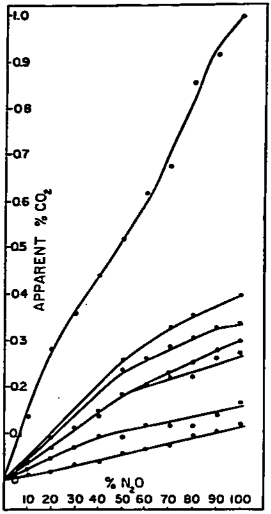

FIG. 1. Spectral overlap: Apparent per cent CO_2 as a function of concentration of N_2O in O_2. No CO_2 was present. Each point represents a single determination in a particular Capnograph. Lines connect determinations in particular Capnographs.

Results and Discussion

All machines were linear for CO_2 in O_2 within 5 per cent of any scale reading of CO_2, *e.g.*, when 6.0 per cent CO_2 in O_2 was analyzed, the scale readings of all machines fell between 5.7 and 6.3 per cent CO_2. The errors caused by spectral overlap resulted in apparent CO_2 concentrations from 0.08 to 0.7 per cent when analyzing 70 per cent N_2O in O_2 and from 0.1 to 1.0 per cent when analyzing 100 per cent N_2O (fig. 1). It therefore behooves each investigator to measure this effect for his own equipment. The error can be corrected either by mechanically zeroing the analyzer or by adjusting the calibration graph.

The correction factor (K) for collision broadening was calculated from the equation:

$$K = y/x$$

where y = the pen deflection of R per cent CO_2 in O_2; x = the pen deflection of R per cent CO_2 in T per cent N_2O, balance O_2; R represents any CO_2 concentration from 1 to 10 per cent, and T represents any concentration of N_2O between 50 and 80 per cent. These data are shown in table 1 and graphically presented in figure 2. To use the correction factor (K), a calibration graph is constructed with known percentages of CO_2 in O_2. The value obtained from this graph for each

TABLE 1. Correction Factors (K) for Collision Broadening of Seven Capnographs*

	Per Cent Carbon Dioxide in Oxygen									
	1	2	3	4	5	6	7	8	9	10
50 per cent N_2O inspired										
Mean	0.983	0.950	0.945	0.941	0.935	0.920	0.919	0.916	0.915	0.914
SE	0.019	0.013	0.024	0.019	0.019	0.013	0.005	0.004	0.004	0.004
70 per cent N_2O inspired										
Mean	0.942	0.926	0.913	0.906	0.901	0.899	0.896	0.888	0.887	0.886
SE	0.014	0.022	0.023	0.020	0.016	0.014	0.014	0.005	0.005	0.004
80 per cent N_2O inspired										
Mean	0.921	0.903	0.891	0.884	0.882	0.878	0.872	0.877	0.875	0.874
SE	0.029	0.027	0.030	0.025	0.020	0.018	0.017	0.005	0.004	0.003

* Means and standard errors refer to seven Capnographs, with one measurement in each machine for each entry in the table.

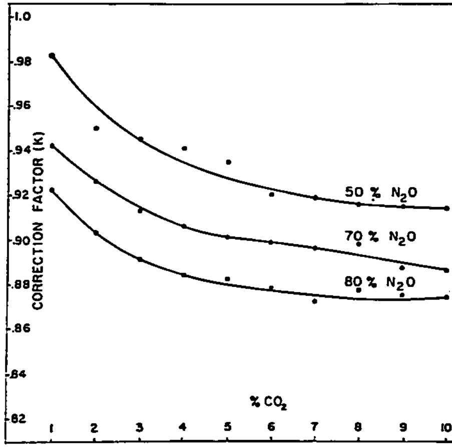

FIG. 2. Correction factor (K) for collision broadening as a function of FI_{N_2O} and true FE_{CO_2}. Each point represents the mean value for seven Capnographs, with one determination per machine.

percentage of CO_2 is then divided by the appropriate K to develop the calibration line for the percentage of N_2O of interest. The variation among machines was sufficiently small that use of these mean correction factors is accurate enough for most research purposes.

Since in anesthesia research it is rare that FE_{N_2O} can be conveniently measured, we have chosen our data in terms of FI_{N_2O}. However, our data can be recalculated and expressed in terms of FE_{N_2O}. The correction factors (K) then have a mean value of 0.131 per percentage N_2O in the background gas (range 0.000–0.271; standard error 0.006).

Machine age was not statistically significantly correlated with the magnitude of either the collision broadening or the spectral overlap error. Rank correlation coefficients were 0.16 and 0.0, respectively ($P > 0.6$ for both).

The correction factors we have determined apply to N_2O only. Smith[9] attempted to measure the collision broadening due to halothane and water vapor and found the effect to be immeasurably small. From this, we surmise that collision broadening errors caused by enflurane and isoflurane would be insignificantly small.

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