Title: NON-UNIFORM INTERFERENCE BY WATER VAPOR IN THE ENGSTROM EMMA

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Introduction. A gas analyzer, the Engstrom EMMA, has been introduced for clinical monitoring of volatile anesthetics. The transducer is a coated quartz crystal which can absorb or release anesthetic molecules. The change in the crystals' resonance frequency is proportional to the concentration of the gas being measured and is shown on a concentration meter as volume percentage. According to the manufacturer, the instrument may be used in one of four configurations: these include measurement of anesthetic concentrations at the fresh gas outlet of the anesthetic machine, within the inspiratory or expiratory limb of the anesthesia circle or at the junction of the endotracheal tube and y-connector (end-tidal). The operators' manual specifies interference by water vapor of 0.2 and 0.3 percent actual reading at 25°C and 35°C respectively.[1] No change in the magnitude of the interference is specified with regard to the anesthetic mode selector switch, i.e., halothane, enflurane, and isoflurane. It was our clinical impression that the water vapor interference was non-uniform with respect to different anesthetic agents and exceeded specifications. We designed a test procedure to quantify the interference produced by water vapor.

Methods. The test procedure consisted of four phases. Each phase involved recording the percent reading from a calibrated EMMA when exposed to various heated and/or humidified combinations of O_2 and anesthetic vapors. Anesthetic vapor concentrations were simultaneously measured by a calibrated Beckman LB-2 gas analyzer. Temperatures were determined by a laboratory grade mercury thermometer positioned at the inlet port of the EMMA sensor. Saturated water vapor was provided by an inline Bird heated humidifier. Observations were confirmed on a second EMMA. Phase I: dry, heated O_2 (26°-38°C) with the EMMA mode selector in the halothane, enflurane and isoflurane position. Phase II: dry, heated (26°-38°C) halothane and isoflurane in O_2 at multiple concentrations (0-3%). Phase III: heated (26°-38°C) humidified (100%) O_2 with multiple concentrations of halothane and isoflurane (0-3%). Phase IV: heated (26°-40°C) humidified (100%) O_2; mode selector in the halothane, enflurane or isoflurane position.

Results. In Phase I (heated dry O_2 only) the EMMA was consistently within the zero drift as specified by the manufacturer ($<$ 0.2% over a 10 hour period). In Phase II (dry O_2 plus anesthetic vapor) the EMMA demonstrated excellent correlation ($r = .99$), linearity and accuracy when compared with the Beckman for halothane and isoflurane. This relationship was maintained over a wide range of temperatures, (25°-38°C) and concentrations of anesthetic vapor (0-3%). The equations for halothane and isoflurane respectively at 25°C were $Y_H = 1.01X - .04$, and $Y_I = 1.06 - .08$, where Y equals % reading by EMMA and X equals % reading by Beckman. In Phase III (humidified O_2 plus anesthetic vapor) the EMMA correlated well ($r = .99$) with the Beckman and remained linear over a temperature range of 26°-38°C, and anesthetic concentrations of 0-3 percent. However, accuracy deteriorated with increasing temperatures. This can be seen in Fig. 1 for halothane. Equations for isoflurane at 26°, 30°, 34°, and 38°C, respectively were $Y_{26} = 1.0$[illegible]$X + .32$, $Y_{30} = 1.12X + .58$, $Y_{34} = 1.14X + .75$, and $Y_{38} = 1.13X + 1.12$. Results for Phase IV (heated humidified O_2 only) are graphically displayed in Fig. 2. The linearity and correlation ($r > .97$) for the data in Phase IV was maintained at all temperatures measured (26°-40°C). Y-intercepts for 26°C were: halothane .26%, enflurane .22% and isoflurane .33% reading by the EMMA.

Discussion. We have shown that the presence of water vapor causes non-uniform interference in the Engstrom EMMA, and that it is in excess of the manufacturer's specifications. The magnitude of H_2O vapor interference is constant for a particular temperature, humidity and mode selector setting. It rises in a linear fashion from 26° to 40°C but is not equal for different selector settings. Water vapor interference with the EMMA selector in the isoflurane position was significantly higher than in the halothane or enflurane position ($P < .01$). The interaction between water vapor and anesthetic vapor is additive, as evidenced by comparing Y-intercepts determined in Phase III with the corresponding Y values seen in Phase IV. Our data suggest that the EMMA may be unsuitable for applications other than measuring dry anesthetic vapor concentrations at the outlet of the anesthetic machine. Certainly, accuracy of the EMMA for in-circle and end-tidal measurements will depend upon a precise knowledge of temperature and humidity of the gas being measured.

Fig 1

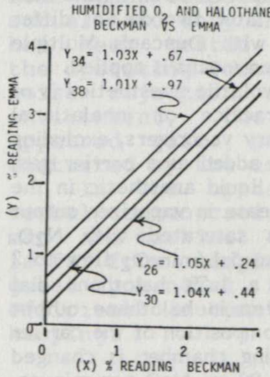
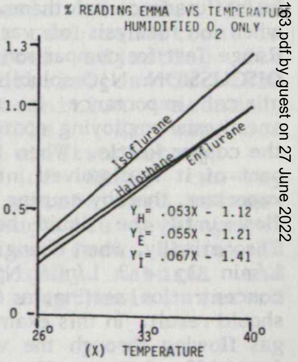

HUMIDIFIED O_2 AND HALOTHANE
BECKMAN VS EMMA

Fig 2


% READING EMMA VS TEMPERATURE
HUMIDIFIED O_2 ONLY

Reference:
1. Engstrom EMMA Users Instructions; Publication 57-10932-31, December, 1980