Title: CONTINUOUS MONITORING OF INSPIRATORY AND END-TIDAL ANESTHETIC VAPOR USING A PIEZOELECTRIC DETECTOR

Authors: J.K. Hayes, M.S., D. R. Westenskow, Ph. D., W. S. Jordan, M.D.

Affiliation: Department of Anesthesiology, The University of Utah School of Medicine, Salt Lake City, Utah

A rugged, compact and fast analyzer is needed for routine clinical measurement of anesthetic vapor concentration. Engstrom® has developed a relay with a piezoelectric quartz crystal. This study measured the accuracy, response time, gas interference, and water vapor dependence of this analyzer to assess its usefulness in clinical practice.

Methods. After calibration the accuracy of the analyzer was measured using calibrated anesthetic gas standards (AGS) containing 2.0% ethane balance Nz, and .75% halothane balance Nz. Response time (0-90% response) was measured using 2% halothane in oxygen at flows of 5, 10, and 15 liters per minute. Twenty measurements were made at each flow rate. Gas interference due to Nz, CO2 and Nz were measured with flows of 5L/min. Humidity effect at 25°C, 30°C, 34°C, and 37°C was measured by humidifying oxygen with a flow rate of 10 L/min then passing it through the analyzer.

The analyzer was evaluated clinically in a study of fifteen healthy children (ages 5 to 16 years). The children were intubated following sodium thiopental induction (4 mg/kg) and maintained with 60% Nz and 40% 02. An anesthesia humidifier, an in-circuit hygrometer, and the gas analyzer were placed between the "Y" connector and the endotracheal tube. Each patient was monitored for approximately 15 minutes before a volatile anesthetic agent was introduced.

Results. Twenty measurements with each gas standard had an average difference between the analyzer output and the gas standard of .016 ± .003 Vol %. Response times at 5L, 10L and 15L per minute were: .71 ± .07 sec., .26 ± .02 sec., and .17 ± .01 sec. respectively. The analyzer showed negligible interference for Nz or O2 but was slightly affected by CO2 (.01% + .005 reading in 5% CO2) and NzO (.11% + .007 reading in 100% NzO).

The analyzer was affected by water vapor in both the laboratory and clinical testing. As the temperature of the humidified oxygen increased, the analyzer offset increased as shown in fig. 1. The offset at 25°C, 30°C, 34°C, and 37°C was .25% ± .04, .51% ± .03, .80% ± .04, and 1.09% ± .04 respectively. Expressed in a linear equation: OFF SET (Vol%) = .0692 * Temp (°C) - 1.52 with R² = .98.

The clinical data showed a water vapor offset which coincided with the laboratory data. (fig. 1) The mean offset for the clinical data was .72% ± .08 at 33.12°C.

Conclusion. In clinical practice an instrument which measures vapor concentration is needed in three areas: to monitor the concentration delivered by the gas machine, to measure average breathing circuit concentrations, and to measure end-tidal concentrations.

The Engstrom analyzer accurately measured dry anesthetic vapor concentration making it applicable for testing the dry gas concentrations delivered by an anesthesia machine.

For the measurement of average inspired or expired anesthetic concentrations in the breathing circuit the analyzer should be accurate and insensitive to interfering gases. The analyzer showed some interference from NzO, and CO2 but water vapor interference resulted in a large offset of 1.09% at 37°C and 100% relative humidity. This offset can be compensated for if the gas temperature and relative humidity remain constant. If they can be controlled the analyzer can be used for in-circuit monitoring.

For end-tidal monitoring the analyzer must have a response time on the order of 50 ms and must be insensitive to interfering gases. The analyzer's dry gas response times decreased from 71 mcs at 5L/min to 17 mcs at 15L/min. Inspiratory flow rates are typically well above 15 L/min so it is reasonable that these response times would be adequate for end-tidal monitoring. The change in offset caused by water vapor at each breath can cause errors; if the analyzer was used for end-tidal monitoring due to changes in water vapor concentration during each breath. It is not possible to see these effects within each breath because of the long time constant of the water vapor effect, 7.32 ± .34 sec. at 10L/min., but they do give considerable uncertainty as to the actual offset. It seems that relative inspired-expired differences can be measured but absolute end-tidal measurements will be in question.

![Figure 1. Lab data (circles, squares). Clinical data (stars).](image-url)