

## Monitoring End-tidal Ethanol Concentrations during General Anesthesia

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AS many as 40% of patients who present with traumatic brain injury have positive blood-alcohol test results.<sup>1</sup> Small, portable devices designed to measure ethanol concentrations in exhaled breath have been used extensively by law enforcement officials to estimate blood-alcohol measurements accurately in drunk drivers.<sup>2</sup> In the case of patients who have an altered mental status or who do not emerge promptly from anesthesia, these devices may provide a quick and low-cost means of identifying ethanol as a contributing factor. Although the use of infrared technology for end-tidal ethanol measurements in anesthetized patients is limited by interference from volatile anesthetics, the effect of volatile anesthetics on the accuracy of electrochemical sensors has not been evaluated fully. In addition, there is only limited information available about the influence of acetone, acetoacetate, and  $\beta$ -hydroxybutyrate on the accuracy of electrochemical sensors. Blood concentrations of these compounds are increased in diabetic ketoacidosis. Because these substances are volatile, they are present in exhaled gases and may interfere with the electrochemical detection of ethanol.

Using a commercially available device, we determined whether the presence of any of these substances (volatile anesthetics or ketones) cause the analyzer to indicate

a value other than 0 in the absence of ethanol, and we then tested whether there was a correlation between end-tidal values and blood-alcohol concentrations in sheep anesthetized with 1.5% isoflurane.

### Materials and Methods

A handheld end-tidal ethanol analyzer (Intoxilyzer S-D2, CMI, Inc., Owensboro, KY) was purchased for use in this study. This battery-powered monitor weighs 250 g and uses an electrochemical fuel cell for measurement of ethanol concentration in air. When properly calibrated, its accuracy is better than  $\pm 5\%$ . Measurements are obtained in approximately 60 s. The device was calibrated according to the manufacturer recommendations using room air and a calibration gas obtained from the manufacturer that contained 0.105% ethanol. When the device is triggered, a spring-operated bellows aspirates 1.5-cm<sup>3</sup> sample of end-tidal gas for analysis.

#### In Vitro Study

In this study, we sought to determine whether volatile anesthetics, in 0-2 minimum alveolar concentration (MAC) and in the presence of 60% nitrous oxide, had an effect on the zero point of the device. Using a standard anesthesia machine, the breathing circuit was ventilated with 60% nitrous oxide, oxygen, and varying concentrations of isoflurane, sevoflurane, and desflurane. The volatile anesthetics were administered using calibrated vaporizers, and actual concentrations in the circuit were confirmed using a volatile agent analyzer (Ultima; Datex Medical Instrumentation Inc., Helsinki, Finland). To allow intermittent sampling of the anesthetic gas mixture by the ethanol analyzer, a 2-mm hole was drilled into a straight connector, which was placed into the breathing circuit. This configuration minimized dead space in the gas sample obtained by the analyzer. Volatile anesthetic concentrations were increased in approximately 0.2-MAC increments, and simultaneous measurements of volatile agent concentration and the corresponding ethanol analyzer reading were recorded.

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## LABORATORY REPORT

In a second *in vitro* experiment, we investigated whether common ketones could interfere with the readings of an electrochemical device in the presence of volatile anesthetics. We diluted acetone, acetoacetate, and  $\beta$ -hydroxybutyrate in deionized water in concentrations up to four times higher than the highest plasma concentrations observed in patients with severe diabetic ketoacidosis.<sup>3-5</sup> The solutions were allowed to equilibrate in sealed flasks for 30 min at 37°C. Through a burr hole in the stopper, 15 ml saturated vapor was aspirated into a gas-tight syringe. Then, 15 ml isoflurane (2% in air) was aspirated into the same syringe from an anesthesia circuit. A sample of the resulting 30-ml gas mixture was aspirated into the ethanol analyzer, and the reading was recorded.

#### In Vivo Study

With approval of the Institutional Animal Care and Use Committee (University of Texas Medical Branch, Galveston, Texas), we evaluated the accuracy of the ethanol analyzer in the presence of isoflurane. Two sheep that weighed 32 kg were anesthetized with ketamine and isoflurane. After tracheal intubation, their lungs were mechanically ventilated with 1.5% isoflurane in 50% oxygen and nitrogen. Laboratory-grade ethanol was infused into a jugular vein at a rate of  $4 \text{ g} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$ , up to a total dose of either 0.67 g/kg or 2 g/kg. End-tidal ethanol measurements were obtained before beginning ethanol infusion and at 10–30-min intervals after completion of the infusion. As in the previously described *in vitro* study, gas samples were obtained by attaching the ethanol analyzer to a 2-mm hole drilled into a straight connector, which was attached directly to the end of the endotracheal tube. Samples were obtained at full end-expiration after a 1.0-l tidal volume breath. Simultaneous blood samples were obtained from a femoral venous catheter and analyzed in the hospital clinical laboratory using a Vitros 950 Analyzer (Johnson & Johnson Clinical Diagnostics, Rochester, NY).

#### Statistical Analysis

Data from the ketone body measurements are presented as a scattergram of ethanol analyzer values *versus* concentration of ketoacids for acetone, acetoacetate, and  $\beta$ -hydroxybutyrate (fig. 1). Linear regression was performed on the pooled end-tidal–blood ethanol data obtained from both sheep (fig. 2). Blood and end-tidal values were also plotted *versus* time (fig. 3).

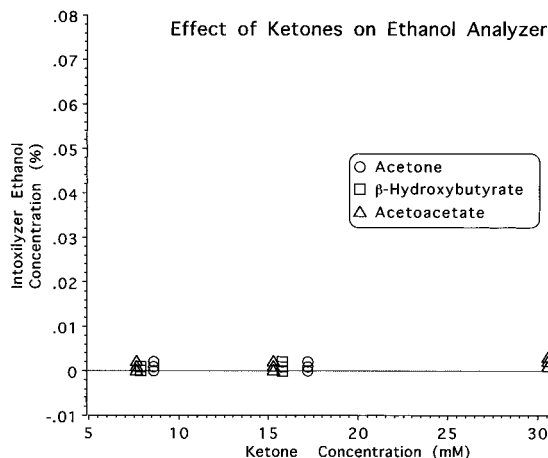


Fig. 1. Effect of different concentrations of acetone, acetoacetate, and  $\beta$ -hydroxybutyrate on the zero value of the ethanol analyzer. None of these ketones, in concentrations up to 32 mM, had an effect on the analyzer.

## Results

#### In Vitro Study

Volatile anesthetics (isoflurane, sevoflurane, and desflurane) in concentrations up to 2 MAC had no effect on the zero value of the ethanol analyzer. All readings on the analyzer were 0.001% or less.

Ketones in concentrations up to 32 mM (acetone, acetoacetate, and  $\beta$ -hydroxybutyrate) did not influence the

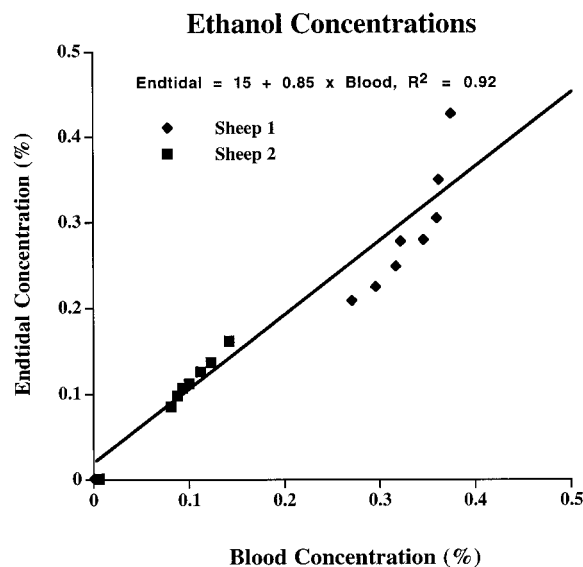
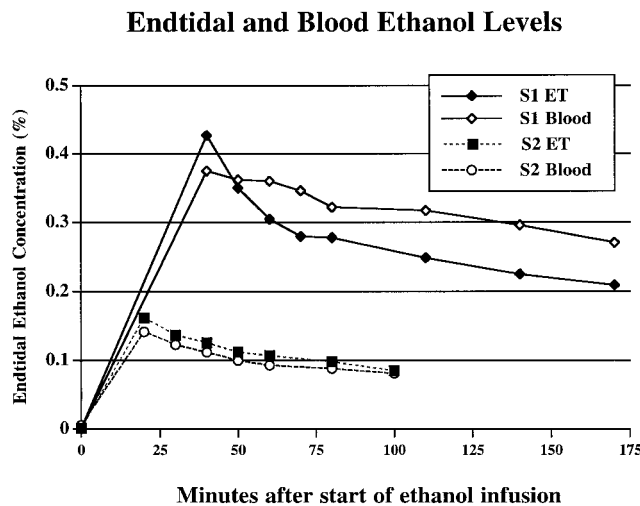


Fig. 2. Linear regression of end-tidal ethanol concentrations of blood–alcohol. Correlation coefficient = 0.92.



**Fig. 3.** Blood and end-tidal (ET) ethanol values *versus* time. S1 = first sheep study (2.0 g/kg ethanol infused); S2 = second sheep study (0.67 g/kg ethanol infused).

zero value of the ethanol analyzer. All readings on the analyzer were 0.003% or less (fig. 1).

#### In Vivo Study

Linear regression of end-tidal *versus* blood values of ethanol concentrations showed a good correlation ( $r^2 = 0.92$ ) over a range of blood ethanol from 0 to 0.4% (fig. 2). The best correlation was obtained from the second study (intravenous dose of 0.67 g/kg), in which blood ethanol concentrations ranged from 0 to 0.14%. For reference sake, a blood ethanol concentration of 0.08 or 0.10 is considered to be the legal limit for operating a motor vehicle in most states. Figure 3 shows the paired determinations of blood and end-tidal values *versus* time.

#### Conclusion

This study shows the ability of an electrochemical analyzer to accurately measure end-tidal ethanol concentrations in the presence of volatile anesthetics. Ethanol analyzers that use infrared detection have been unreliable in the presence of volatile anesthetics because these anesthetics share the hydroxy-carbon structure with ethanol that absorbs infrared light at a wavelength of 3.3  $\mu\text{m}$ .<sup>6</sup> This interference by volatile anesthetics can be overcome by use of electrochemical detection. In this study, none of the commonly used volatile anesthetics, in concentrations up to 2

MAC, had an apparent effect on the ethanol analyzer, nor did the presence of ketones, which are found in some diabetic patients.

For successful use of the ethanol analyzer, particular attention should be paid to proper use and calibration of the device. The device should be zeroed using room air before measurements are obtained. A two-point calibration with use of a gas of known ethanol concentration is recommended on a monthly basis. To obtain accurate readings, it is important that end-tidal gas be sampled directly from the end of the endotracheal tube. We found that the best way to obtain such a sample is by attaching the gas port of the ethanol analyzer directly to the circuit *via* a 2-mm hole drilled into a straight connector. Attempting to attach sampling tubing to the analyzer increases dead space and is likely to result in an erroneously low value. Electrochemical detectors are not specific for ethanol and may sense the presence of any type of alcohol in end-tidal gas. Our data confirm previous reports that the electrochemical sensor is not influenced by acetone<sup>7</sup> and show that it is not influenced by acetate or  $\beta$ -hydroxybutyrate. In patients with severe diabetic ketoacidosis, acetone may be metabolized to isopropanol, which could interfere with accurate measuring of ethanol concentrations.<sup>8</sup> Because concentrations of isopropanol created by metabolism of acetone are small, this interference probably would be an issue in forensic cases only. In a clinical setting, this interference plays a minor role, and the electrochemical sensor should give reliable readings, even in patients with severe diabetic ketoacidosis.

This device may be useful to anesthesiologists in examining patients who may be intoxicated and present to the operating room for emergency surgery. Although a blood-alcohol measurement yields the same information as an end-tidal measurement, many hospitals do not offer blood-alcohol determination 24 h/day, 365 days/yr. Even if such a service is available, there are often significant delays in transportation of the blood sample to the laboratory and in performance of the assay.

Although a positive result from an end-tidal test for ethanol may provide an explanation for an altered mental status or indicate delayed emergence from anesthesia, coexisting medical conditions must also be considered, including the presence of other central nervous system depressants or intracranial disease.

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