CASE REPORT

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Breath Alcohol Analysis in One Subject with Gastroesophageal Reflux Disease

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ABSTRACT: A large number of people suffer from the heartburn symptoms associated with gastroesophageal reflux disease (GERD). Relatively little has been published on its potential for biasing a breath alcohol measurement. The present case describes an individual (white male, aged 23) who experimentally consumed 1.0 g/kg of an alcohol beverage and subsequently provided breath and blood samples for analysis. Breath expirograms were also collected following several different preexhalation breathing maneuvers. Shortly after the end of drinking the mean of replicate breath alcohol results exceeded that of the corresponding venous blood alcohol. A later paired comparison (during the postabsorptive phase) showed the blood alcohol to exceed the breath. None of the expirograms provided evidence that "mouth alcohol" due to gastroesophageal reflux had biased any test results. People with GERD can provide biased-free end-expiratory breath alcohol results where sound forensic practice is followed, which includes: 15-min. preexhalation observation, duplicate testing, instrumental detection systems, and trained alert operators who ask appropriate questions and watch for associated signs.

KEYWORDS: forensic science, gastroesophageal reflux disease, breath alcohol, mouth alcohol

Gastroesophageal reflux disease (GERD) is a clinical disorder occurring where the lower esophageal sphincter is compromised and unable to restrict the flow of stomach contents back up into the esophagus (1). Sufferers may experience varying degrees of regurgitation along with significant heartburn discomfort. Studies have shown that approximately 7% of persons in the United States experience heartburn symptoms daily while nearly 60% experience it intermittently (2,3). Treatment for GERD ranges from life style changes and over-the-counter antacids to surgery in extreme cases.

GERD may present a potential risk for biasing a forensic breath alcohol measurement through the introduction of alcohol from the stomach back into the oropharyngeal cavity ("mouth alcohol"). With per se breath alcohol legislation in most jurisdictions, GERD is becoming one of many issues posed to forensic scientists regarding the accuracy and reliability of breath alcohol analysis. The important work of Kechagias et al. (4), the first to experimentally study the forensic implications of this issue, concluded there was little risk of bias to breath alcohol measurement in patients with severe conditions of GERD. The following work presents a case report and attempts to suggest some additional ways to measure the effect of GERD through the evaluation of breath alcohol exhalation curves (expirograms). Subjects with GERD should not automatically be considered incapable of providing reliable breath alcohol results. However, confidence in test results can be enhanced where sound forensic protocol is routinely followed and instrument operators are alert for specific conditions while questioning the subject and administering the test.

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Materials and Methods

The subject, a white male aged 23, had been arrested for drunk driving and subsequently provided duplicate breath samples in accordance with administrative rules into a BAC Datamaster infrared breath alcohol instrument (National Patent Analytical Systems, Inc., Mansfield, OH). The results were 0.114 and 0.123 g/210 L, which exceeded the statutory limit of 0.08 g/210 L. Prior to trial, the subject complained of suffering from GERD and presented supporting medical documentation. An arrangement was worked out with the prosecutor, the subject, and the Washington State Patrol Breath Test Section to reduce the charged offense if the subject complied with a controlled drinking experiment.

The subject, weighing 160 lb, consumed eight one fluid ounce drinks of 80 proof Vodka mixed either with orange juice or Sprite. This dose (1.0 g/kg) was determined from Widmark's method (5) in order to achieve a blood alcohol concentration (BAC) near 0.10 g/100 mL at 2 h following the start of drinking. The drinks were consumed as four "doubles" within 1 h and 9 min after he finished breakfast approximately 2.75 h previously.

Immediately following each drink, the subject rinsed the mouth thoroughly with water, which was then swallowed in order to minimize the "mouth alcohol" effect. Duplicate breath samples were then provided into a BAC Datamaster instrument. The mean of these values were used to estimate the end-expiratory breath alcohol concentration (BrAC) during the absorption phase of the concentration-time curve. Following the last drink and a thorough rinse with water, the subject continued to provide duplicate breath samples for approximately 1.5 h. Venous blood samples from the cubital vein of the forearm were also collected nearly simultaneously (within 4 min) with duplicate breath samples at 21 min after the last drink and again at 78 min after the last drink. Duplicate breath samples were collected both immediately before and after each of the blood samples.

After the last drink the subject provided breath samples following several different expiratory maneuvers including: normal ventilation, hypoventilation, hyperventilation, belching, and an extremely long exhalation. The breath alcohol expirograms were collected for these various maneuvers employing a separate data acquisition system (Personal Daq, Iotech, Inc., Cleveland, Ohio) attached to the BAC Datamaster instrument. Accuracy and precision estimates for the BAC Datamaster were determined using a Guth 2100 simulator possessing an ethanol vapor target concentration of 0.082 g/210 L. The instrumental systematic error was +2.7% with a standard deviation of 0.0006 g/210 L ($n = 10$).

Results and Discussion

Figure 1 shows the breath alcohol concentration time curve where all points are the mean of duplicate samples. The mean BAC results, plotted as unfilled circles in Fig. 1, are also shown along with their corresponding mean BrAC results in Table 1. The peak BrAC observed in Fig. 1 is the mean of duplicate results: 0.090 and 0.102 g/210 L. Both BrAC sample means (determined from duplicate samples collected immediately before and after the blood sample) exceed the corresponding mean BAC for the first sample. Since all of these samples were collected between 17 and 25 min after the last drink, the subject may still have been in the active absorption phase of his concentration-time curve where arterial blood alcohol (the source of a breath alcohol sample) is expected to be higher than venous blood alcohol concentration. These differences are accounted for by the expected analytical, sampling, and biological variability involved when comparing within-subject breath and blood alcohol concentrations. Although gastroesophageal reflux cannot be ruled out as a potential contributor to the BrAC/BAC differences observed here, these differences are not unusual within the context of breath and blood sampling. Both BrAC sample means were less than the corresponding BAC mean for the second blood sample collected approximately 1 h later and which appears to be in the post-absorptive phase of Fig. 1.

Figure 2 shows the breath alcohol expirogram for the highest (0.102 g/210 L) of the duplicate BrAC results associated with the first blood sample. The mean BAC value is also plotted for reference. The breath expirogram appears normal with no evidence of "mouth alcohol" or unusually large variability. The thermistor voltage, used in the BAC Datamaster to ensure sufficient breath flow rate, is also plotted in Fig. 2 and reveals that the subject maintained a fairly uniform exhalation rate for approximately 15 s. Simultaneous breath and venous blood samples collected near in time to the end of drinking can, on occasion, yield BrAC results in excess of the BAC because of the associated sampling and biological variabilities (e.g., arteriovenous differences).

Figure 3 shows four breath alcohol expirograms associated with the second blood sample collected 78 min after the last drink and ranging from 0.074 to 0.077 g/210 L. All four breath samples were

TABLE 1—*Results and times of corresponding breath and blood alcohol concentrations.*

Breath Sampling Time	BrAC* (g/210 L)	Blood Sampling Time	BAC* (g/100 mL)
1441	0.0960	1445	0.0855
1449	0.0885		
1536	0.0750	1542	0.0810
1545	0.0755		

* Mean of duplicate analyses.

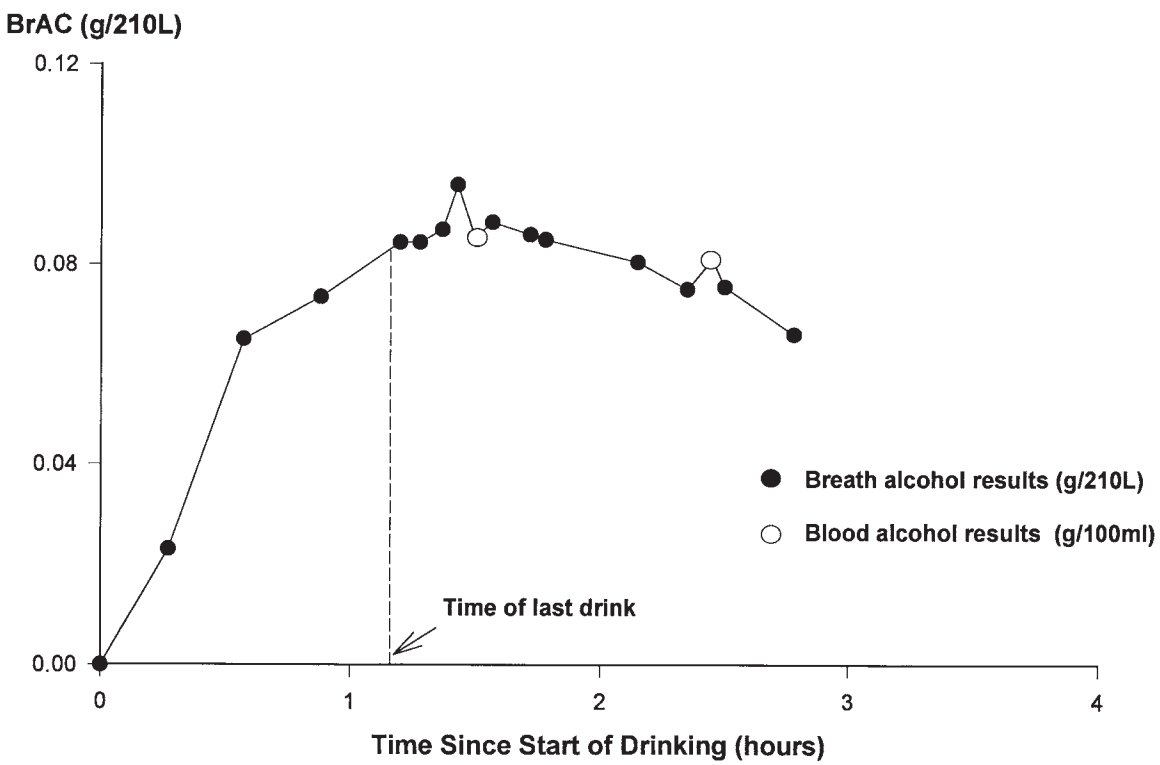

FIG. 1—*The breath alcohol concentration time curve for the subject with GERD. Each point (whether breath or blood) represents the mean of duplicate analyses.*

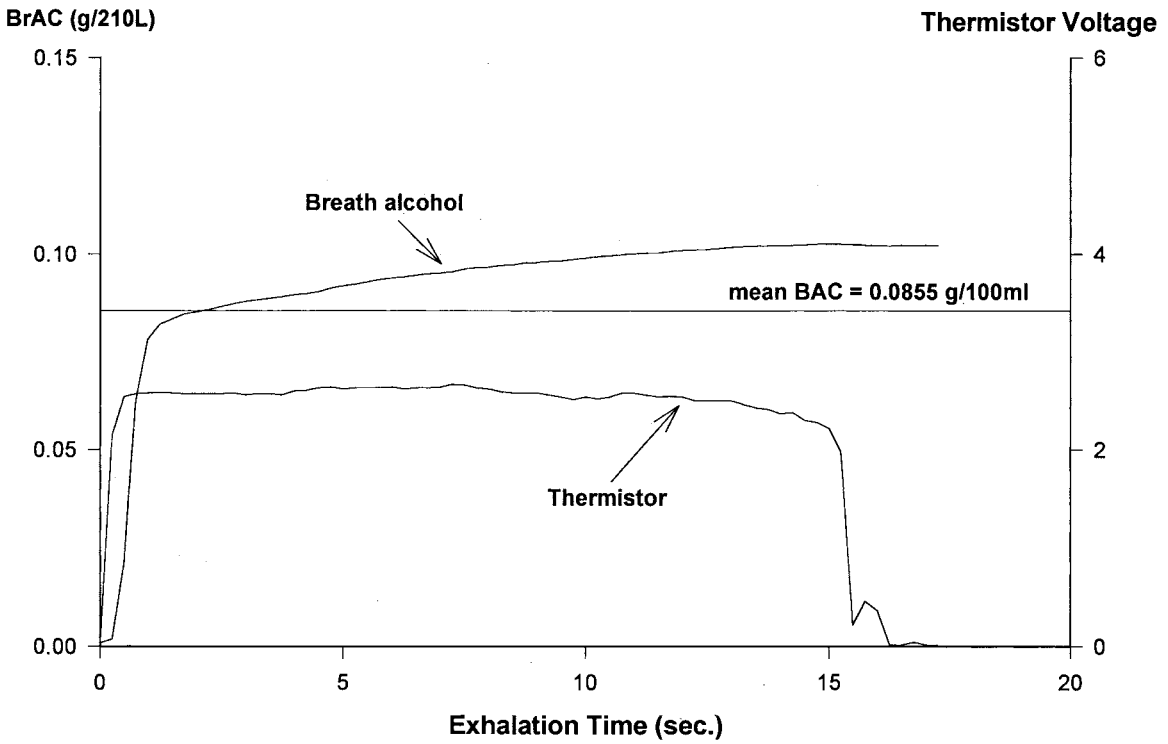

FIG. 2—*Plot of breath alcohol expirogram showing the associated mean blood alcohol concentration along with the thermistor (breath flow rate) trace. This curve represented the maximum single breath alcohol result (0.102 g/210 L) throughout the experiment.*

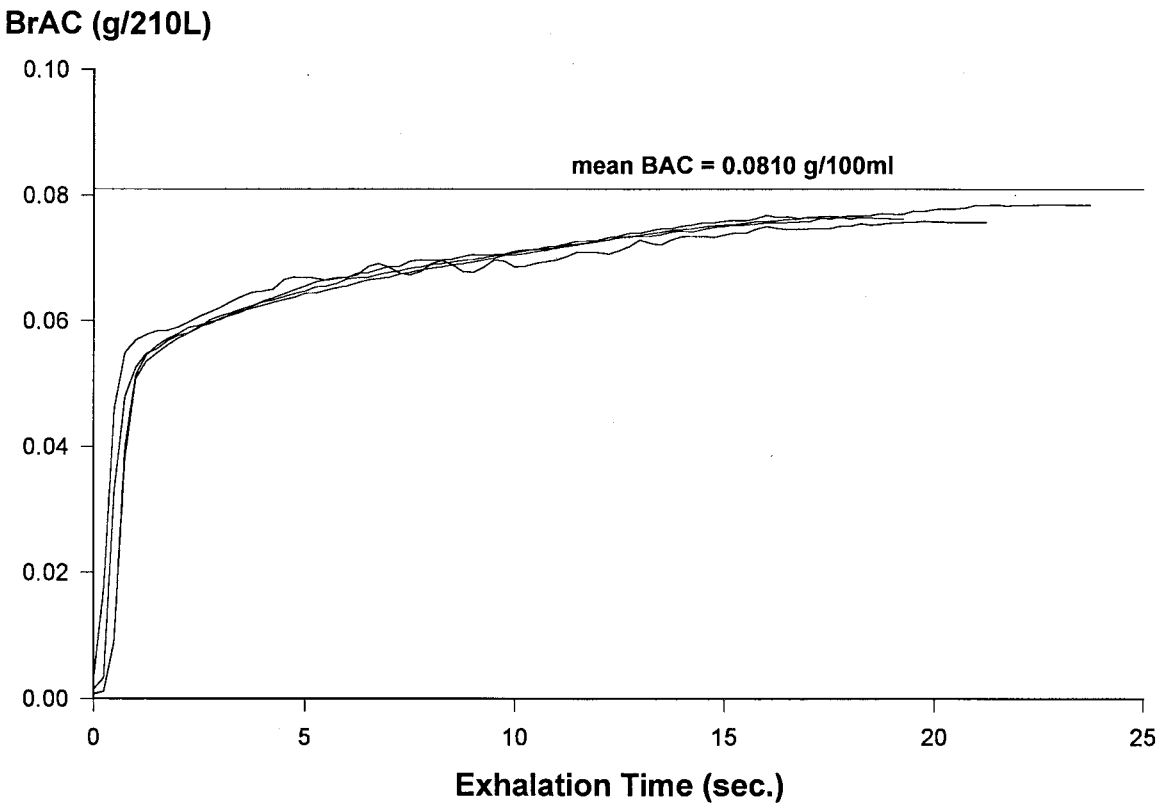

FIG. 3—*Four breath alcohol expirograms along with the associated mean blood alcohol concentration collected approximately 78 min after the last drink.*

collected within 10 min of each other, while the mean of two of them are reflected in Table 1. With the mean BAC result shown for comparison, all four breath alcohol expirograms show very close correspondence along with their apparent asymptotic approach to the corresponding BAC. This pattern is much more typical of simultaneously measured breath and venous blood samples during the postabsorptive phase.

Figure 4 shows the breath alcohol expirograms following preexhalation maneuvers of normal breathing, hypoventilation, hyperventilation, and belching. These typical curves are reflective of their respective preexhalation breathing patterns and show their greatest differences in the early portion of exhalation. These differences reflect the interaction of alcohol and the airways during the first part of exhalation. The hypoventilation condition allows for a more complete equilibration of the upper airway (dead air space region) where the distance between the airway lumen and the blood is much larger than in the alveolar region. The hyperventilation pattern, on the other hand, shows how exhaled alcohol is taken up significantly by the cooler alcohol deficient upper airways during exhalation. Asymptotically, the curves would likely converge to the same limit. The exhalation curve following belching was provided first among the four exhalations. While this curve was the highest of the four (although not forensically significant), it does not appear abnormal or indicative of containing a "mouth alcohol" bias. An expirogram containing "mouth alcohol" is generally noisy along with regions possessing a negative slope (the principle by which the instrument detects "mouth alcohol"). Although the hyperventilation curve remained significantly lower than the others throughout the exhalation times, none of the exhalation curves in Fig. 4 appear abnormal for this subject.

Figure 5 shows an extremely long breath alcohol expirogram from the subject in this study. The individual ran competitively in both high school and college and no doubt had a large forced vital capacity. The individual was instructed to provide as long of an exhalation as possible employing a controlled but steady exhalation maneuver. The thermistor trace shows that the minimum exhalation flow rate required by the BAC Datamaster (as measured by a voltage >1.5 V and corresponding to approximately 3 L/min) was maintained throughout. The individual was able to sustain the exhalation for nearly 60 s. The corresponding mean BAC (collected approximately 15 min after the breath sample) is shown for comparison. The slow asymptotic approach of the BrAC to the BAC is apparent with no evidence of "mouth alcohol" being present.

A forensically sound breath test program employs several quality control features (6) that will minimize the potential bias due to esophageal reflux. A preexhalation observation period (e.g., 15 or 20 min) where the subject has no foreign material within the mouth will eliminate any bias due to recently consumed alcohol. Duplicate sampling and analyses where acceptable agreement is obtained (e.g., within ± 0.020 g/210 L or within $\pm$ 10% of their mean) is particularly important where "mouth alcohol" from any source may occur. This further minimizes the risk of "mouth alcohol" bias because of its exponential elimination pattern. A well-trained and observant operator should notice if the subject experiences a reflux condition that brings material from the stomach up into the mouth. If this occurs, the mouth should be thoroughly rinsed, checked, and another preexhalation observation period accomplished. Instrumental features that monitor for normal breath alcohol expirograms as seen, for example, in Figs. 2 through 5, will also minimize the risk of a mouth alcohol bias due to GERD. However, these instrumental "mouth alcohol" detection features are least reliable for ensuring a biased-free test. Finally, a "static sampling" feature where the measured and reported sample is contained within a closed-sample chamber following the end of exhalation will avoid unusual exhalation vagaries (e.g., sucking back, etc.) and should improve replicate precision.

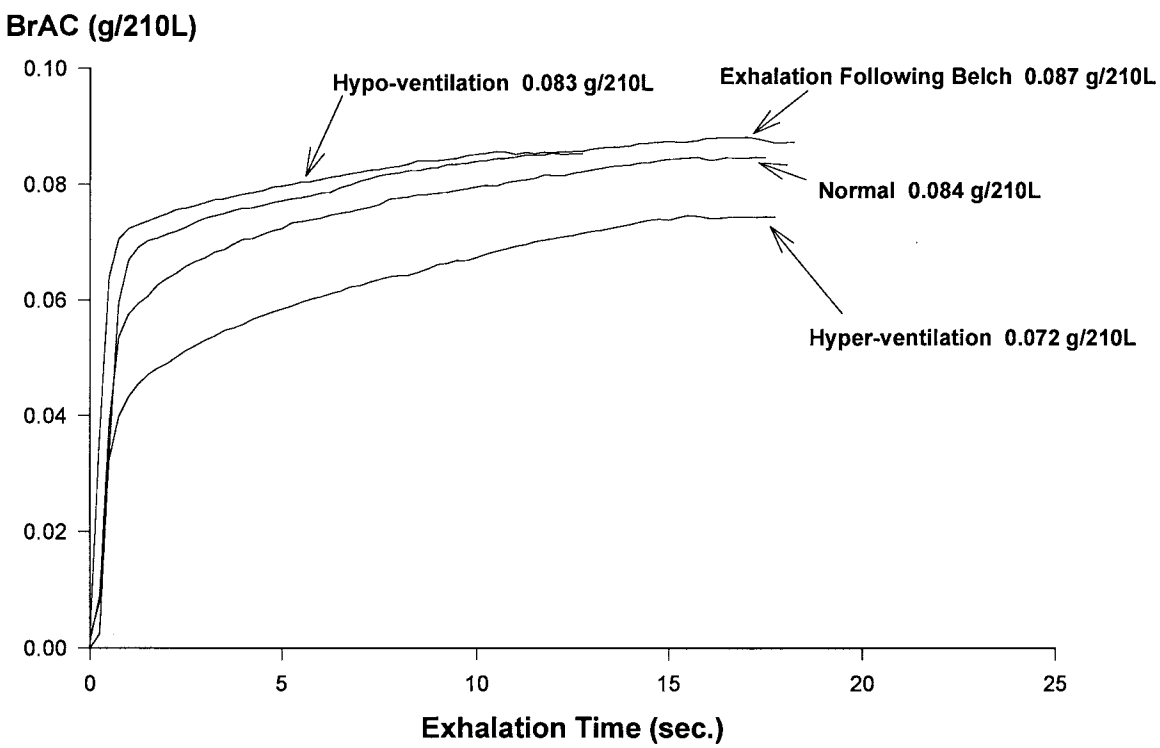

FIG. 4—*Breath alcohol expirograms following normal breathing, hypoventilation, hyperventilation, and belching.*

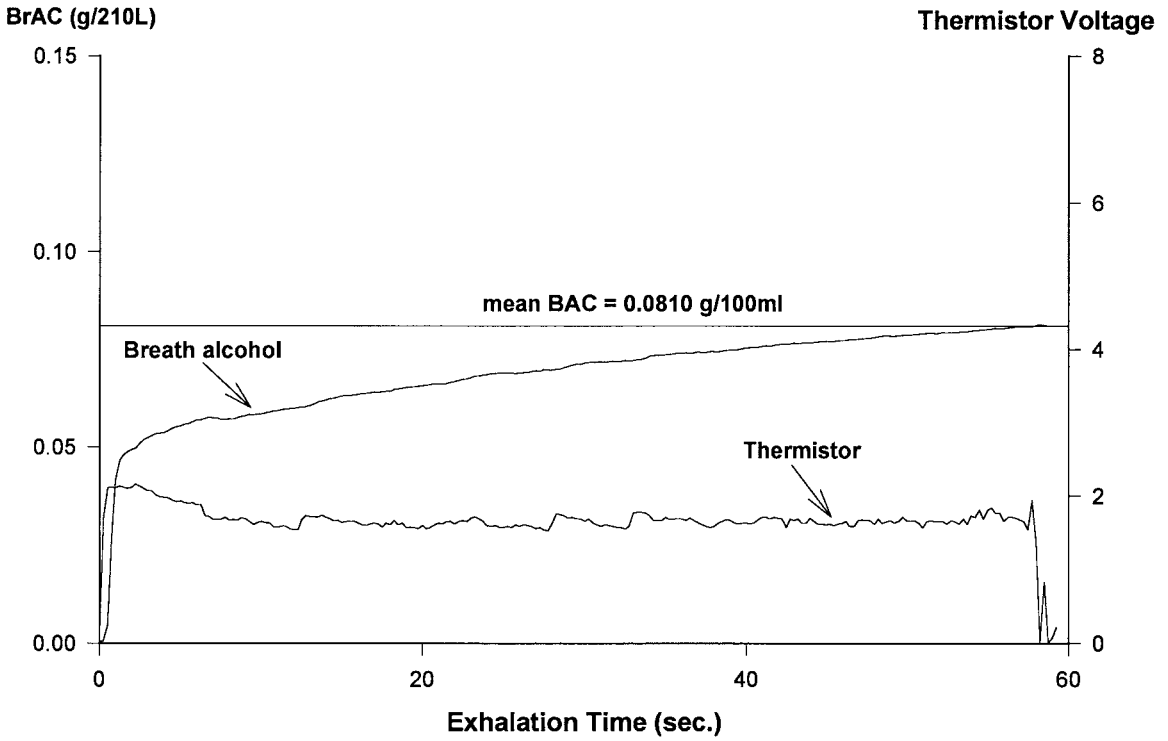

FIG. 5—*A breath alcohol expirogram following a prolonged and controlled exhalation along with the associated mean blood alcohol concentration and thermistor tracing.*

In addition to the appropriate forensic safeguards noted above, several biological considerations help to minimize the potential bias due to gastroesophageal reflux. A partial reflux bringing stomach contents up into the lower portion of the esophagus would not be expected to bias the end-expiratory breath alcohol measurement since the exhaled air would never be in contact with the material. Only a full regurgitation bringing material into the oropharyngeal cavity would cause a concern. Even a full regurgitation would be a concern only if it contained raw alcohol yielding a vapor concentration in excess of that which is coming from the end-expiratory breath. Vapor alcohol in the mouth region that is equal or lower than the end-expiratory concentration would not bias the sample received and measured by the instrument. Full regurgitation, however, would yield foreign material in the mouth and technically require rinsing and a new observation period. Other factors to consider in a particular case would include the time since the last drink and the food contents of the stomach. Alcohol leaves the stomach rapidly with little or no food present. The risk of reflux in GERD patients also appears to increase when they recline and stomach contents are proximal with the lower end of the esophagus. If possible, having a subject with GERD sit while providing the breath samples may be preferred to having them lean over while standing.

While processing a subject for breath alcohol analysis in drunk driving cases, most police officers will question the subject about physical disabilities and illnesses. Particular attention should be paid if the subject mentions they suffer from GERD. Additional insight can be gained by asking specific questions such as: do they take medication for the condition, how long have they experienced the condition, did they experience any type of reflux during the 15 min immediately prior to providing the breath sample, etc. No bias is expected where the operator observes a 15 min period, does not observe any regurgitation of material into the mouth, and duplicate analyses agree acceptably well. Moreover, any belching immediately prior to exhalation will not significantly bias a test result since any gas from the stomach will be exhaled into and out of the instrument sample chamber being replaced by the final end-expiratory sample arriving from the deep lungs. Belching during a continuous exhalation is highly improbable.

Conclusions

Although GERD cannot be ruled out, no evidence of its contribution to biasing the breath alcohol measurements in this experiment can be deduced. All of the breath alcohol expirograms along with their comparisons with venous blood samples appeared very normal for human breath alcohol measurement.

This experiment has demonstrated that persons suffering from GERD are certainly capable of providing reliable, unbiased breath alcohol results. An operator simply needs to ask careful questions and remain alert to the possibility of reflux or regurgitation prior to or during breath sampling. Mention of this pathological condition and its potential for bias should also be noted in the training of breath test instrument operators.

Although the potential for bias in breath alcohol measurement appears to be minimal, more work certainly needs to be done in this area in view of the large number of people who suffer from this condition. Moreover, the present experiment has demonstrated the potential for increasing our forensic understanding of these unusual cases through the cooperative efforts of forensic scientists, prosecutors, attorneys, and the defendant themselves. In unique and unusual forensic cases, studies can be designed and accomplished where everyone involved gains some benefit.

Forensic scientists in breath alcohol test programs should be particularly alert, and train operators as well, to unusual cases where some arrangement can be made to advance our knowledge in particular areas. Many additional opportunities will no doubt present themselves in the future.

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