The Slope Detector Does Not Always Detect the Presence of Mouth Alcohol

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Running Head: Mouth alcohol and the alcohol breath test

ABSTRACT

Infrared absorption alcohol breath test instruments use a “slope detector” which serves two primary functions: the first is to identify “alveolar air” from a flat breath alcohol concentration (BrAC) exhalation profile; the second is to identify the presence of “mouth alcohol” as a decreasing BrAC profile. Because of the normal physiological properties of the lungs, neither of these purposes is accomplished by the slope detectors as designed for breath test units (BTU) used in law enforcement. This study was undertaken to test the hypothesis that the second purpose of the slope detector does not work when alcohol is present in the blood stream as well as the mouth. The data show that the slope detector does not adequately distinguish mouth alcohol when alcohol is present in both the mouth and the blood stream.

KEY WORDS: Forensic science; breath alcohol test; mouth alcohol.

INTRODUCTION

The alcohol breath test is an indirect means of estimating the blood alcohol concentration (BAC). The most important assumption is that after a prolonged exhalation, the end-exhaled breath alcohol concentration (BrAC) accurately reflects the alveolar air, and hence, BAC. Implicit in that assumption is that no alcohol has been added to the breath as it passes from the lungs to the breath-testing unit (BTU). However, if there is alcohol in the oral cavity or pharynx, it will vaporize during exhalation and add to the BrAC. The functions of the slope detector have been designed with the goal of ensuring that a valid alveolar air sample is obtained.

Exhaled breath is monitored during the exhalation to obtain a suitable breath sample. Under normal circumstances, BrAC increases during exhalation. The original developers of the breath test reasoned that the BrAC rise would continue until the alveolar air was obtained, at which point the BrAC would level off. The first purpose of the slope detector is to follow the exhaled BrAC until a flat exhalation profile is achieved indicating the presence of alveolar air to insure that an adequate alveolar sample is obtained. However, because of the continual interaction of alcohol with the airway mucosa during exhalation, it is impossible to get a sample of alveolar air to the mouth without the alcohol concentration changing. The flat slope at the end of exhalation occurs simply because the subject has stopped exhaling. Further details regarding this

mechanism have been described in a prior publication [1], In short, a flat plateau simply means that the subject has stopped exhalation. The flat slope does not mean that alveolar air has been obtained. So the first intended purpose of the slope detector does not work.

The second intended feature of the slope detector, is to determine when mouth alcohol is contributing to the BrAC by identifying a negative slope (a decrease in BrAC as the exhalation proceeds). However, there are conditions when the increasing BrAC exhalation profile superimposes on the decreasing mouth alcohol exhalation profile resulting in a flat exhalation profile. Under such conditions, the slope detector may not detect a decreasing exhalation profile and may not detect the additive effect of mouth alcohol.

During inspiration, air is heated and humidified as it passes through the upper airways [2, 3]. Some water within the mucous layer or watery sub-mucous layer will vaporize and heat stored in the airways will be picked up by the inspired gas and taken to the alveoli. During exhalation, the process reverses; fully humidified air at core body temperature is cooled by the cooler airway mucosa and water vapor condenses onto the mucosa [4]. This water and heat exchange process is vital because it conditions the inspired air to avoid damaging the delicate alveolar cells while conserving water and heat from major loss in the exhaled air. Under normal environmental conditions, exhaled gas has less heat and less water vapor than does alveolar air [4].

The dynamics of soluble gas exchange are similar to the dynamics of heat and water exchange. These processes are analyzed using similar equations. The fact that respired air exchanges heat and water with the airways implies similar alcohol exchange processes [5, 6]. The degree of interaction is directly related to the solubility of the gas in the airway mucosa and mucous lining. The very high solubility of alcohol in water guarantees its strong interaction with airway tissue [7]. Because this interaction depends on temperature and airflow characteristics, variations in tidal volume and frequency can have a substantial effect on the alcohol concentration in the breath sample [8, 9]. This variation is affected by the difference in temperature between the outside air and the alveolar air [10].

The operation of a slope detector is confirmed by operators swishing or gargling some mouthwash (containing alcohol) around the mouth and spitting the mouthwash out. There is no alcohol in the blood at the time of testing. This situation results in an increasing alcohol concentration during exhalation followed by a decreasing alcohol concentration. The decreasing BrAC is identified as a negative slope and triggers an “Invalid” sample indication [11]. However, in subjects having alcohol in their blood stream, the slope depends on the balance between the rising lung alcohol and the decreasing mouth alcohol, which can result in a level (or slightly decreasing) slope and an inability of the slope detector to identify the added mouth alcohol. Only when the mouth alcohol curve has a

large negative slope (< - 0.006 gm/210 Liter for three consecutive data points with a DataMaster), will the slope detector then detect the mouth alcohol and the reading will register as an “invalid sample”.

This study was carried out to determine the conditions under which the slope detector is able (or unable) to detect mouth alcohol in human subjects when the BAC is elevated.

MATERIALS AND METHODS

We used two commercially available BTUs: BAC Verifier DataMaster (DM) and Intoxilyzer 5000 (INT). Both have similar alcohol detection systems and slope detectors. Normal human volunteers (n = 8) consumed alcohol until reaching a BrAC of approximately 0.10 gm/210 L. The subjects were tested with either a DM or an INT regularly to follow the BAC profile. After the post-absorptive phase was seen on 4 consecutive breath tests (declining values after a peak of absorption), the subjects were asked to swish a small amount (< 0.25 oz) of 80 proof liquor around in their mouth (over a 4-5 second period) and spit out the contents. Breath alcohol tests were then performed at regular intervals (approximately 2 – 3 minutes).

The detector voltage, which is proportional to the measured ethanol concentration from the BAC DataMaster [11] (National Patent Analytical Systems,

Inc., Mansfield, Ohio) was measured. The detector voltage signal for alcohol concentration was converted to g/210L by analyzing the signal during the standard simulator test. Expired lung volume was measured with a digital spirometer (KORR, Medical Technologies Research Spirometry System, Salt Lake City, Utah) placed inline with the breath tube of the BAC DataMaster. Both the EtOH signal and expired volume signal were recorded at 10 Hz with PowerLab (A-D Instruments, Colorado Springs, CO) on a PowerPC.

RESULTS

In most (but not all) cases, the swishing of alcohol immediately leads to an invalid sample (indicative of a negative slope and the detection of mouth alcohol), sometimes followed by another invalid sample. After two or three tests, valid samples were obtained that exceeded the BrAC prior to the swishing. Figures 3 and 4 show consecutive breath tests from one subject after the subject swished alcohol in his/her mouth. In Figure 3, the initial breath test was an “invalid” sample, followed three minutes later by a valid test (BrAC = 0.113 gm/210 L). After an additional 6 minutes, a valid breath test of 0.042 gm/210 L was obtained. This last test was presumably close to the blood alcohol because it was similar to the BrAC prior to mouth alcohol and decreased slowly (at the approximate normal burn-off rate.

In the second sequence of tests (Figure 4), the first “invalid” test was obtained at 3:10 pm after consumption of three additional one-once shots of 86-proof scotch. If the subject had stopped exhalation at approximately 1.75 liters exhaled, the reading would have been a valid ≈ 0.31 gm/210 L. Three minutes later, the DM read a valid reading with BrAC = 0.149. An additional 4 minutes wait yielded a breath sample of 0.089. After an additional 9 minutes, the BrAC was 0.076, the likely correct breath sample, as it was approximately the same as the BrAC was prior to the mouth alcohol tests.

Further results from the other six subjects: three tested with the Intoxilyzer and three tested with the DataMaster are shown in Table 1. After the BrAC tests had stabilized (indicating alcohol absorption has been completed), each subject swished approximately 0.1 oz of alcohol and then took breath samples at two-minute intervals. In all cases there were valid breath samples that exceeded the pre-mouth-alcohol BrAC. In all cases but one the test following the mouth alcohol was an invalid sample. In the first subject using the DataMaster, the first sample registered a valid 0.164, which was markedly greater than the baseline 0.064. On average the first valid sample read 0.098 ± 0.071 gm/210 L (mean ± SD) greater than the baseline. The valid breath samples did not return to the baseline until 15 minutes had passed.

DISCUSSION

Using normal procedures for testing the slope detector, the operator will swish some mouthwash (with alcohol) and then exhale into the breath test machine. These operators do not have alcohol in their blood stream. Under these conditions, exhaled BrAC will increase to a maximum and then decrease resulting in an “invalid sample”.

In a limited study using only three subjects, Evans [12] showed that a positive BrAC test can be obtained in subjects with no blood alcohol within 10 minutes of taking in mouth alcohol. This author did not study subjects with alcohol in their blood stream. Wigmore [13] studied nine female and twenty-one male alcohol-free subjects after introducing 10 ml of diluted alcohol (20% v/v alcohol) into their mouths. The subjects either rinsed the alcohol for 10 s and then expectorated or immediately swallowed. Each subject then provided breath samples into an Intoxilyzer 5000 at 5 and 10 min post-administration for both conditions. They found valid positive tests in 28 out of 120 tests. They found that the mouth alcohol effect was greater for rinsing than for swallowing alcohol. This study is interesting in that the subjects had only minimal blood alcohol levels.

Gastroesophageal reflux disease (GERD) is a condition that may cause mouth alcohol due to the reverse flux of stomach contents into the nasopharynx

resulting in the possibility of mouth alcohol. Kachagias [14] studied 5 female and 5 male subjects with GERD asking whether elevated breath alcohol tests might result. Two of the four individual subject data shown indicated the possibility of an elevated BrAC. The authors concluded: “the risk of alcohol erupting from the stomach into the mouth owing to gastric reflux and falsely increasing the result of an evidential breath alcohol test is highly improbable. However, these authors studied only a very limited number of subjects leaving open the possibility that GERD may play a role in other subjects. In a related study, Staubus [15] showed that burping with alcohol in the stomach provided a falsely high BrAC of up to 0.046 g/210 L.

Generally, it is thought that mouth alcohol will be rinsed away by saliva within 15 minutes in some states and 20 minutes on other states. Thus states will require either a 15-minute or 20-minute waiting period to precede a breath alcohol test. A concern has been those subjects with dentures, particularly using adhesives. Harding [16] studied 25 subjects who used dentures with and without their dentures for the retention time of mouth alcohol. These authors found that mouth alcohol lasted more than 15 minutes in 5 out of 25 subjects without dentures and 5 out of 25 subjects with dentures and adhesives. They also found that mouth alcohol lasted more than 20 minutes in no subjects without dentures and 2 out or 25 subjects with dentures using adhesives. A case study by Trafford [17] indicated that there was a possibility of dentures contributing to a falsely high breath test.

In addition, a study by Logan et al [18] showed that medications in asthma inhalers were eliminated with a 15 minute observation period and hence, asthma inhalers will not contribute to mouth alcohol if taken more than 15 minutes before a breath test.

Because of the inadequacies of the slope detector, extra precaution must be used to be certain that mouth alcohol is not contributing to a breath test. The practice in many states is to perform two breath tests within a short time (2-5 minutes). If the two breath tests are identical to each other in magnitude, then it is unlikely that mouth alcohol is present.

Some states take only one breath test. This is dangerous because the role of mouth alcohol would be overlooked. In Alaska, only one breath test is used. The practice is to not require an additional 15-minute waiting period after obtaining an “invalid sample”. Thus, as seen in Figures 3 and 4, it is likely that the following valid breath test will be greater than the correct BrAC if it is administered before an additional 15 minutes waiting period is completed.

In our experiments, we also noted a propensity for an erroneous high BrAC test during the absorption phase. This may be due to the potential for mouth alcohol to be missed by the slope detector immediately after consumption of alcohol. Jones [19] has observed that BrAC is sometimes greater than the

venous blood sample BAC within the first 90 minutes (the absorptive phase) following ingestion.

In summary, this study has shown that mouth alcohol may play a role in many breath tests even though a BTU uses a slope detector. While slope detectors are present in all modern infrared absorption BTUs, they are not useful in many cases. This problem with the slope detector argues quite strongly that duplicate breath tests with 15 min between tests should be used in all cases in order to minimize the chance of mouth alcohol influencing the breath test result.

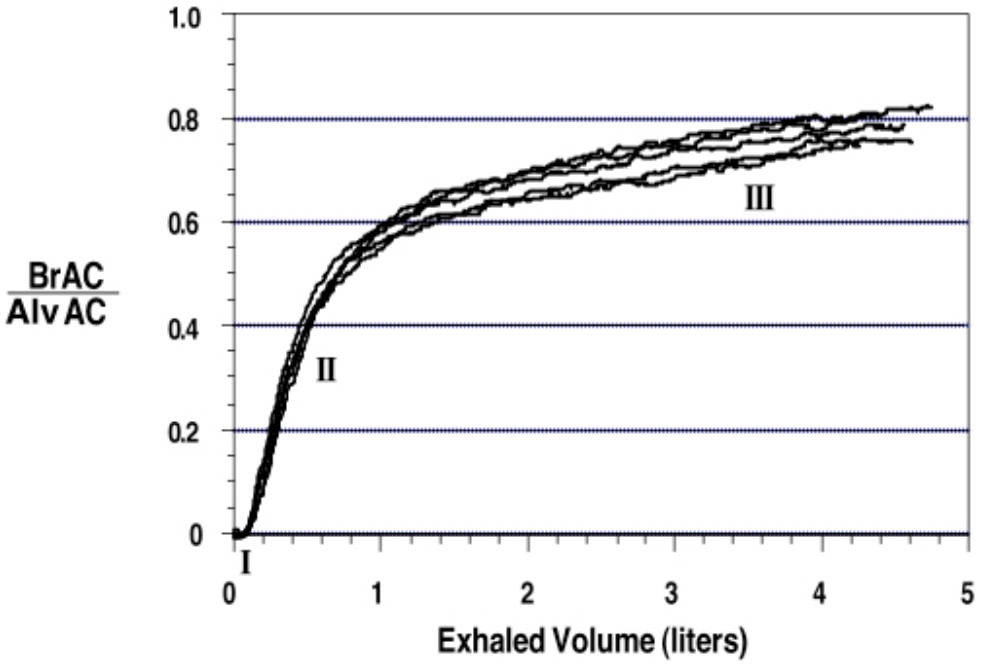

Figure 1. Exhaled alcohol profile from normal subject (modified from 9). Breath alcohol concentration (BrAC) normalized by alveolar alcohol concentration (Alv AC) vs. exhaled volume in liters. Continued exhalation results in an increasing BrAC. The BrAC depends on the exhaled volume.

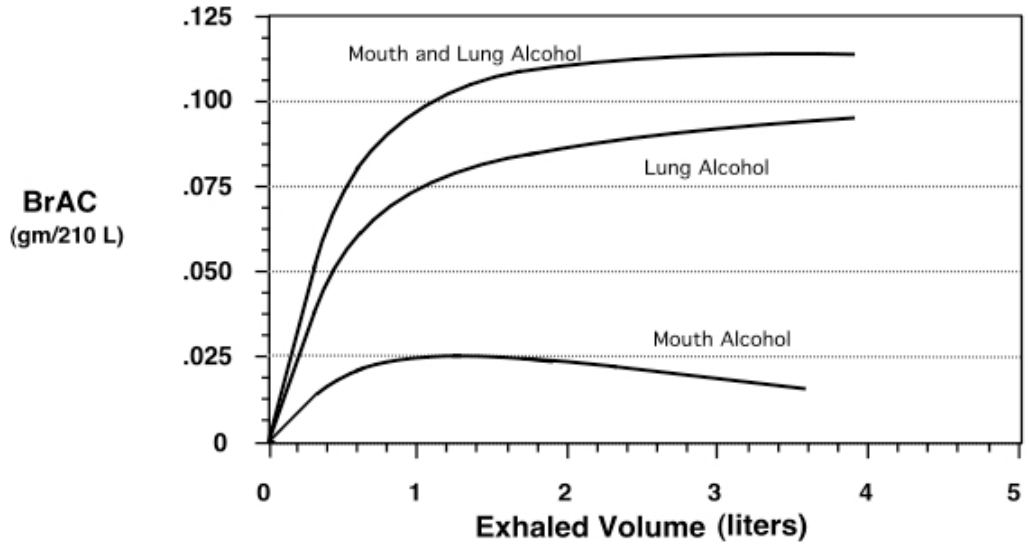

FIGURE 2. Exhaled breath alcohol profiles. The lower curve is obtained with alcohol dissolved in the mouth with no alcohol in the blood. The middle curve is obtained with alcohol in the blood with no alcohol in the mouth. The top curve is the sum of the two other curves obtained with alcohol in the blood and alcohol dissolved in the oral mucosa (modified from (17)).

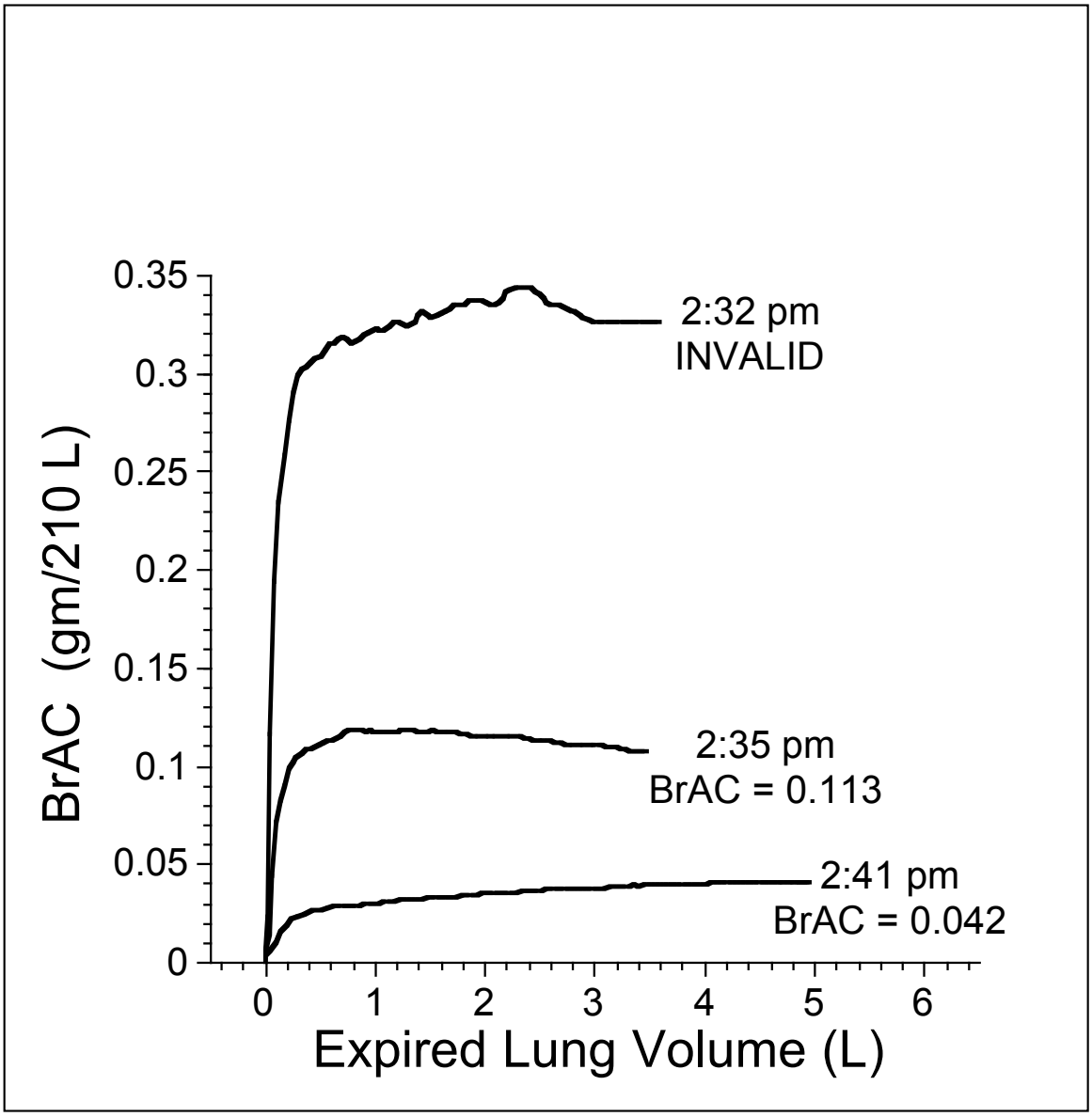

Figure 3. Several exhalation profiles for breath alcohol tests taken at intervals after sipping of 80 proof alcohol. An invalid sample is followed by two valid breath tests: one influence by mouth alcohol without mouth alcohol being detected.

Figure 4.

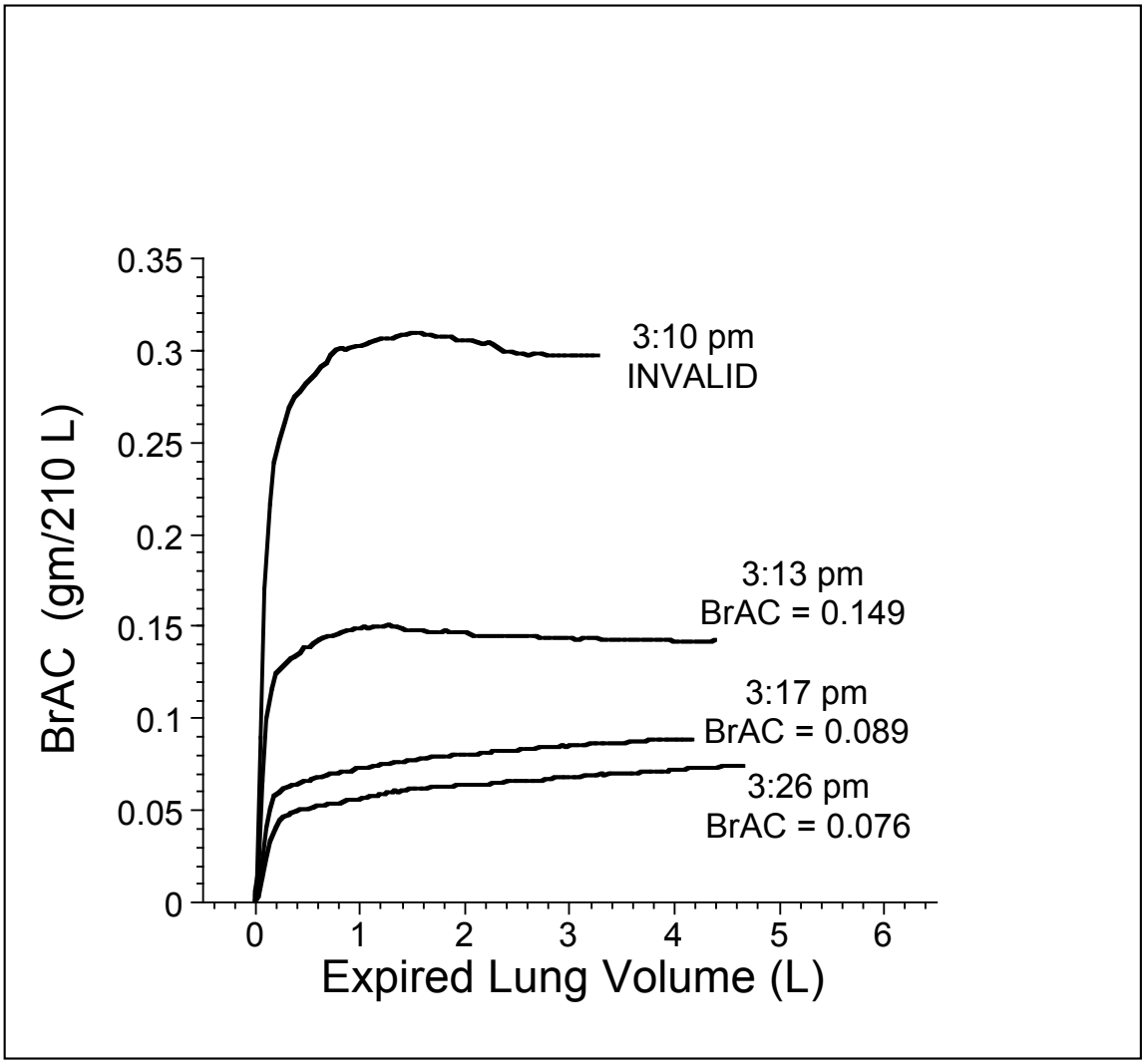

Figure 4. Several exhalation profiles for breath alcohol tests taken at intervals after consuming three one-ounce shots of 86 proof scotch. An invalid sample is followed by a three valid breath tests: the first two are influenced by mouth alcohol without an indication of mouth alcohol detection.

Table 1. Erroneously high, valid BrAC after mouth alcohol. Tests were performed at approximately two-minute intervals.

Stabilized Post-Absorptive Value		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
Intoxilyzer 5000								
0.090	MA	INV	INV	0.169	INV	0.089		
0.050	MA	INV	INV	0.250	INV	0.087	0.066	0.056
0.064	MA	0.164	INV	0.075	0.070	0.059		
DataMaster								
0.133	MA	INV	INV	INV	0.168	0.146	0.130	
0.091	MA	INV	0.249	0.161	0.130	0.108	0.105	0.090
0.102	MA	INV	INV	0.118	0.103	0.099		

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