Bedside Diagnosis of Alcohol Intoxication with a Pocket-Size Breath-Alcohol Device: Sampling from Unconscious Subjects and Specificity for Ethanol

Marianne Falkenason,1 Wayne Jones,2 and Bo Sörbo1

We describe a novel mouth-cup device for sampling breath from unconscious subjects and analysis with a hand-held breath-alcohol instrument, the "Alcolmeter SD-2." This equipment was evaluated in healthy volunteers after they drank a moderate dose of alcohol. Three kinds of breath were analyzed: (a) end-expired air from a conventional mouth-tube, (b) breath sampled from the mouth-cup, and (c) air from a nasal tube supplied with the breath analyzer. The ethanol concentration in breath from the mouth-cup was slightly less than in end-expired air but significantly greater than in nasal air. Results with mouth-tube and mouth-cup correlated highly with blood-ethanol concentration as determined by gas chromatography; nasal-tube air correlated less well. The Alcolmeter responded not only to ethanol but also to methanol, 1-propanol, and 2-propanol, whereas ethylene glycol gave no response. The time–response curve for methanol was different, and this might permit differential diagnosis of methanol poisoning.

Additional Keyphrases: emergency procedure · blood alcohol concentration compared as measured directly · test specificity · electrochemical techniques

Emergency-service patients are often affected by alcohol, and on-the-spot diagnosis of intoxication is sometimes essential (1, 2). It is important to know if a patient is unconscious because of an intracranial hematoma, thus requiring immediate surgical intervention, or from the effects of ethanol (3–5). A person's blood-alcohol concentration (BAC) is widely used as evidence of impairment, but quantitative analysis of blood is time consuming and involves intricate laboratory procedures. Instead of measuring BAC directly, some investigators advocate using breath analysis as a quick and easy bedside test of alcohol influence (6–11). The possibility of sampling and analyzing breath from unconscious or uncooperative subjects was recognized early, but the technique was not evaluated further (12). Indeed, when the concentration of alcohol in breath aspirated through a nasal tube was compared with BAC (6, 9), the results obtained were lower and showed more variability compared with analysis of end-expired air. The present work deals with the design and evaluation of a novel mouth-cup device for passive sampling of breath in unconscious subjects.

Another important aspect of breath-alcohol analysis at an emergency unit is the specificity of the instrument response for ethanol. A rapid diagnosis of intoxication caused by methanol or ethylene glycol is important and desirable, because of the high toxicity of the metabolites formed (13, 14). We therefore tested the specificity of the "Alcolmeter SD-2" when exposed to air–vapor mixtures of alcohols other than ethanol.

Materials and Methods

Subjects. Six ostensibly healthy individuals (three men and three women), all accustomed to moderate drinking, took part in this study. Their ages ranged from 28 to 62 y and their body weights were between 55 and 78 kg. About 2–3 h after their last meal, the subjects received 800 mg of ethanol per kilogram of body weight in the form of a drink made from 930 mL/L ethanol diluted with orange juice to give a total volume of 300 mL. The drink was consumed during 30 min, and samples of venous blood were taken at 30- to 60-min intervals via an indwelling needle. The samples were stored for two or three days at 4 °C before analysis. Blood was drawn into 5-mL Vacutainer Tubes containing sodium fluoride and heparin (Becton Dickinson & Co., Rutherford, NJ). At about the same time that blood was sampled, the breath-alcohol concentration was determined as described below.

Equipment. The Alcolmeter SD-2 (Lion Laboratories Ltd., Barry, Wales, U.K.), a pocket-size device, was used for analysis of alcohol in breath by means of an electrochemical detector (15). The instrument is calibrated to read directly in terms of BAC on the basis of a 2300:1 blood/breath ratio of ethanol (16). The Alcolmeter was calibrated with ethanol-in-air standard vapors corresponding to 100 mg/dL BAC equivalent; these were generated from pressurized cans (NALCO MN-1) supplied by Lion Laboratories. The instrument response appears as a digital display, in increments of 5 mg/dL BAC equivalent. The resolution of this particular digital scale will limit the precision of breath-alcohol measurements to ±5 mg/dL.

Sampling and analysis of breath. End-expired air was obtained in the normal way in accordance with the manufacturer's instructions by passing the last portion of a prolonged exhalation through a mouth-tube (Figure 1a).

The mouth-cup device (Figure 1b) was designed to obtain samples of breath from unconscious subjects. We made the sampler from a disposable polypropylene cup such as is used in many hospitals for dispensing medicines. The volume of the cup was 30 mL, top diameter 4.5 cm, height 3 cm, and bottom diameter 3.7 cm. (The exact dimensions are not critical.) A hole was made through the bottom of the cup to give a tight fit with the rim of the mouth-tube ordinarily supplied with the instrument. During sampling, the operator holds the mouth-cup firmly over the subject's lips with one hand, and the Alcolmeter is held in the other hand. The subject's nostrils are closed with a nose clip, and the subject is allowed to make several inspirations and exhalations to flush out deadspace air from the sampling system. Finally, the operator notes the movements of the subject's thorax and presses the sampling button during an exhalation phase.

We also took a specimen of breath by aspiration directly from the nasal cavity, using the nasal tube supplied with the instrument. This is a polypropylene tube, 1.5 cm ×
Results

Breath-alcohol and BAC profiles. Figure 2 shows average curves for the concentrations of ethanol in venous blood compared with the three kinds of breath specimen. In the interval 30–180 min after the subjects started to drink, the BAC estimated from analysis of end-expiratory air was higher than in venous blood, but the concentrations later became more or less equal. BAC according to results with the mouth-cup device and the nasal tube were lower than venous BAC for the entire concentration–time profile.

Table 1 presents a correlation-regression analysis of the results, and the relevant scatter plots are displayed in Figure 3. All three kinds of breath sample were well correlated with venous BAC, but the standard error estimates and the slopes of the regression lines differed significantly. The magnitude of the regression coefficients suggests that the Alcolmeter readings are, on average, 4% too high for mouth-tube specimens as compared with venous BAC and 11% and 41% too low for mouth-cup and nasal-tube air, respectively. The 95% confidence limits for the regression coefficients (slopes) overlapped for mouth-tube and mouth-cup samples of breath, implying no statistically significant difference. The 95% limits on the regression line for the nasal samples differed significantly. The variability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mouth-tube</th>
<th>Mouth-cup</th>
<th>Nasal tube</th>
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<tbody>
<tr>
<td>Slope</td>
<td>1.04 ± 0.043</td>
<td>0.89 ± 0.033</td>
<td>0.59 ± 0.051</td>
</tr>
<tr>
<td>95% confidence limits</td>
<td>0.95–1.12</td>
<td>0.82–0.96</td>
<td>0.49–0.90</td>
</tr>
<tr>
<td>Intercept, mg/dL</td>
<td>3.8 ± 3.02</td>
<td>-1.3 ± 2.36</td>
<td>9.9 ± 3.39</td>
</tr>
<tr>
<td>S, mg/dL</td>
<td>8.56</td>
<td>6.58</td>
<td>8.41</td>
</tr>
<tr>
<td>r</td>
<td>0.94 ± 0.039</td>
<td>0.95 ± 0.036</td>
<td>0.81 ± 0.069</td>
</tr>
<tr>
<td>n</td>
<td>78</td>
<td>78</td>
<td>74</td>
</tr>
<tr>
<td>y, mg/dL (range)</td>
<td>16–140</td>
<td>10–125</td>
<td>18–72</td>
</tr>
</tbody>
</table>

Regression analysis of venous BAC (x) and breath-alcohol concentration (y) obtained with three different sampling arrangements; mouth-tube, mouth-cup, nasal tube. r = correlation coefficient, S, = standard error estimate, degrees of freedom = n – 2.

* P < 0.01 from unity. * P < 0.01 from zero. * P < 0.01 from the other breath samples.

Fig. 2. BAC as estimated by breath analysis with the Alcolmeter and in venous blood (Δ) by gas chromatography in six subjects after they drank 0.8 g ethanol per kg body weight

Breath was sampled with a conventional mouth-tube (Δ), mouth-cup (O), and nasal tube (◦). Vertical bars illustrate inter-subject variations, expressed as ±1 standard error.
of the blood–breath correlates as reflected in the magnitude of scatter and the statistic $S_{xy}$ was least for the mouth-cup samples and greatest when the nasal tube was used for sampling breath.

Table 2 gives some preliminary results from actual emergency hospital situations with apparently alcohol-intoxicated patients. The breath tests were carried out by the staff on duty, and the results showed satisfactory agreement with venous BAC.

**Specificity.** Figure 4 gives time–response curves for analysis of air–vapor mixtures of various alcohols that might be encountered in the breath of intoxicated subjects admitted to a casualty unit. For ethanol, 1-propanol, and 2-propanol, the time–response curves were similar, but the peak response was less for 2-propanol compared with 1-propanol. The response to methanol was markedly different, and the maximum result was not reached even 50 s after sampling, in contrast to the other alcohols, which gave a constant reading after 30 s. No response was obtained for ethylene glycol.

**Discussion**

The blood- and breath-alcohol profiles determined in this work agreed fairly well for all subjects and confirm reports in the literature concerning the reliability of the Alcolmeter when end-expired air was obtained with a mouth-tube (19). Indeed, the Alcolmeter is used worldwide as a preliminary breath-alcohol screening device for traffic-law enforcement. The breath-alcohol response observed 30–120 min after drinking is probably higher because end-expiratory air equilibrates with the pulmonary arterial BAC, not venous BAC. During the early stages of absorption and distribution of alcohol into tissue water, the pulmonary arterial BAC tends to exceed the venous BAC. This arterial–venous difference becomes less as the absorption and distribution of alcohol reach completion. The blood/breath calibration factor used (2300:1) was derived for near-simultaneous samples of post-absorptive venous BAC and end-expired alveolar air (16).

Our results from analysis of breath samples obtained...
with the nasal tube agree fairly well with those of Gibb et al. (8), who found considerably lower values compared with venous BAC. We could also confirm the report of Wenzel and McDermott (9), who noted a poor correlation between blood and breath when passive samples were obtained with the aid of a nasal tube. It seems likely that breath samples collected by aspiration from a nasal cavity might easily become diluted with alcohol-free room air, thus accounting for the lower results. This suspicion prompted us to develop an improved sampling arrangement based on the mouth-cup device for use with unconscious subjects.

Analysis of breath with the Alcolmeter is not a specific method for determination of ethanol. The electrochemical sensor responds to other alcohols such as methanol, 1-propanol, and 2-propanol (20). We now find that the time-response curve for methanol differs from these other alcohols. This might enable tentative identification of methanol in the breath of unconscious patients as follows. If the instrument reading after 50 s is significantly greater than that after 30 s, then the presence of a high concentration of methanol is indicated, and appropriate action should be taken (13). The instrument response to air–vapor mixtures of 2-propanol was only about half that for 1-propanol, probably because primary alcohols are oxidized to aldehydes and secondary alcohols to ketones. Acetone, the product of 2-propanol oxidation, resists further oxidation. The lack of response to acetone was noted earlier (20). Unfortunately, ethylene glycol gave no response on the Alcolmeter, presumably because of the low volatility of this compound (21).

We conclude that Alcolmeter SD-2 is a useful device for bedside analysis of alcohol at hospital emergency units. The results obtained with the mouth-cup device agreed with venous BAC and end-expired breath much better than did samples obtained through the nasal tube. A certain skill and training are needed to obtain breath samples from unconscious subjects.

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References