Screening of Exhaled Breath by Low-Resolution Multicomponent FT-IR Spectrometry in Patients Attending Emergency Departments

Olli Laakso 1,2,*, Matti Haapala 3,4, Tapio Kuitunen 5,6, and Jaakko-Juhani Himberg 7

1 Hyvinkää Hospital, Department of Anesthesiology and Intensive Care Medicine, Sairaalankatu 1, 05850 Hyvinkää, Finland; 2 University of Helsinki, Institute of Clinical Medicine, Division of Anesthesiology and Intensive Care Medicine, P.O. Box 22, 00014 University of Helsinki, Finland; 3 University of Helsinki, Laboratory of Physical Chemistry, P.O. Box 55, 00014 University of Helsinki, Finland; 4 Temet Instruments Oy, Pulttitie 8, 00880 Helsinki, Finland; 5 Jorvi Hospital, Department of Medicine, Turuntie 150, 02740 Espoo, Finland; 6 Porvoo Hospital, Department of Medicine, Sairaalantie 1, 06150 Porvoo, Finland; and 7 HUCH Laboratory Diagnostics, P.O. Box 340, 00029 HUS, Finland

Abstract

Interest in noninvasive methods for disease diagnosis is increasing. In this study, we tested the utility and potential of a portable Fourier transform infrared (FT-IR) multicomponent analyzer in the emergency rooms (ERs) of two Finnish hospitals. Major detected breath volatiles in this population were ethanol, carbon monoxide, methane, and acetone, in addition to carbon dioxide and water. The analysis of breath revealed an ethanol concentration of over 25 ppm (0.1 g/L in blood) in 56 out of 589 patients (9.5%). During nightshifts the proportion was 30% for all and 63% for trauma patients. Five-hundred eighty-four patients had measurable carbon monoxide in their breath. A breath carbon monoxide of over 4 ppm (4.4 pg/L) differentiated smokers from nonsmokers. Methane over 2 ppm (1.3 pg/L) was detected in the breath of 32% of the participants. Methane concentration was higher among aged patients. Two-hundred ninety-eight participants had detectable acetone in their breath. Elevated exhaled acetone [10–76 ppm (23–75 pg/L)] was detected in 10 patients. The FT-IR method proved functional in the ER setting. A major advantage over blood sampling was fast and easy analysis performed by nonlaboratory personnel.

Introduction

Expired human breath contains information on substances in blood because only a slender barrier separates the air in the alveoli of the lung from the blood in capillaries. Volatile compounds, such as ethanol, diffuse across the alveolar membrane from the compartment with the higher vapor pressure to the one with the lower—from the blood into the air or vice versa (1). Breath tests have been used for many purposes, for example, to detect solvent exposure (desired or accidental) and to diagnose gastrointestinal or metabolic disorders. Even inflammation or peroxidation processes can be evaluated by analyzing breath samples (1). Fast noninvasive breath tests could be potential assets for physicians in emergency rooms (ER) or for paramedics on field sites. At present, there is no suitable equipment available for such purposes. IR spectroscopy is one of the fastest methods to analyze gas mixtures, such as expired air, without preparing the sample (2). A quantitative IR analysis of components in a gas mixture is possible, even if their characteristic IR absorption spectra overlap or unknown compounds exist. The problem of spectral overlap has been tackled by applying chemometric methods, such as classical least-square methods, to digitized Fourier transform IR (FT-IR) spectral data (3).

We have previously tested a portable low-resolution FT-IR multicomponent point-of-care breath analyzer in detecting solvent intoxications. The analyzer proved accurate and precise in laboratory tests and human experiments for simultaneous measurement of methanol and ethanol in exhaled breath (4, 5).

The aim of this investigation was to screen and elucidate major breath volatiles in the Finnish ER patient population. In addition, the utility and potential of the analyzer in the hands of nonlaboratory personnel in ER settings was evaluated.

Experimental

Apparatus

The FT-IR spectrometer (Gasmet™, Temet Instruments Oy, Helsinki, Finland) is a pilot-case-sized point-of-care analyzer weighing 18 kg. It was equipped with a Temet carousel interferometer and a continuous flow White-type multipass gas cell. The gas cell volume was 200 mL, the absorption path length 2.0 m, and temperature 50°C. The IR radiation source was silicon carbide. A Peltier-cooled mercury cadmium tel-

* Author to whom correspondence should be addressed: Olli Laakso, Hyvinkää Hospital, Department of Anesthesiology and Intensive Care Medicine, Sairaalankatu 1, 05850 Hyvinkää, Finland. E-mail: olli.laakso@ppl inet.fi.
luride detector was operated in the wavenumber range of 4000–900 cm⁻¹. All the spectra were measured at an 8-cm⁻¹ resolution at a rate of 10 scans/s (5). The analyzer was run on a 12V battery. Theoretically, an 8-h analyzing time was feasible without charging. The analyzer and battery/charger were placed on a pushcart for easy bedside access. Single-use bacterial filters (Pall BB25™, Pall Industries Ltd., San Diego, CA) were connected to the sampling hose were used as a mouthpiece and to protect the analyzer from contamination (Figure 1). The dead space before the measuring cell (consisting of the sampling hose and the bacterial filter) was 50 mL.

The analyzer was equipped with multicomponent analysis software (Calcmet™, Temet Instruments Oy). The reference library included IR spectra for ethanol, methanol, isopropanol, acetone, methyl ethyl ketone, methyl isobutyl ketone, methyl tert-butyl ether, ethyl acetate, toluene, butane, methane, nitrous oxide, carbon monoxide (CO), carbon dioxide (CO₂), and water. All these components were analyzed in one assay. Before the study, the analyzer was inspected and calibrated in cooperation with the manufacturer. The IR spectra of each single component were measured in appropriate concentrations and stored in the reference library.

Different reference concentrations of gaseous substances (CO, CO₂, methane, butane, and nitrous oxide) were prepared by diluting certified reference gases with nitrogen. The flow of gases was controlled by Brooks SL5850 mass-flow controllers (Emerson Process Management, Brooks Instrument, Hatfield, PA).

Reference spectra for liquids were made by a Gasmet calibrator (Temet Instruments Oy). It contained a syringe pump (Cole-Parmer 74900 series, Cole-Parmer Instrument Company, Vernon Hills, IL), a manual needle valve, a mass flow meter (Aalborg GFM17, Aalborg Instruments & Controls, Orangeburg, NY), and a stainless steel injection chamber (Figure 2). The syringe pump injected precise amounts of liquid into a heated N₂ gas flow in the injection chamber. Hamilton 25-, 50-, or 100-μL syringes (Hamilton 1700-series™, Hamilton Company, Reno, NV) were used, depending on the target concentration. The injected liquid was vaporized rapidly, and a continuous flow of a sample gas was produced. The chamber was heated to 2°C below the boiling point of each component.

The components used for calibration were ethanol (99.7 vol-%, Primalco Ltd., Helsinki, Finland), methanol (> 99.8%, Labscan Ltd., Dublin, Ireland), isopropanol (> 99.5%, Acros Organics, Geel, Belgium), acetone (> 99.5%, ProLabo, Briare, France), methyl ethyl ketone (> 99.5%, Riedel-de Haén AG, Seelze, Germany), methyl isobutyl ketone (> 99%, Riedel-de Haén AG), methyl tert-butyl ether (99.8%, Fluka Chemie GmbH, Buchs, Switzerland), ethyl acetate (> 99.5%, Merck KgaA, Darmstadt, Germany), toluene (> 99.5%, Merck KgaA), butane (0.100% in N₂, ± 2% relative analytical accuracy, Messer Griesheim GmbH Specialty Gases, Krefeld, Germany), methane (105 ppm in N₂, ± 2% relative analytical accuracy, AGA, Riihimäki, Finland), nitrous oxide (1062 ppm in N₂, ± 2% relative analytical accuracy, Messer Griesheim GmbH Specialty Gases), carbon monoxide (100 ppm in N₂, ± 2% relative analytical accuracy, AGA), and carbon dioxide (9.96 vol-% in N₂, ± 2% relative analytical accuracy, AGA).

The detection limits (DLs) of components were determined by analyzing 30 samples resembling plain exhaled breath (2.5% H₂O and 4.9% CO₂ in N₂). These samples were generated by bubbling a certified CO₂/N₂ mixture through water. DLs were calculated by using the equation DL = 3 × SD, where SD = standard deviation of analysis results of the component in question. The DLs of all components were under 2 ppm (ethanol 1.6 ppm, acetone 0.7 ppm, carbon monoxide 0.9 ppm, and methane 1.0 ppm, for example).

**Materials and Methods**

The study was carried out in the ERs of two hospitals and two municipal health care centers in Hyvinkää and Porvoo, Finland. The Hospital of Hyvinkää is a 242-bed hospital with a catchment area of 155,000 inhabitants. The Hospital of Porvoo has 176 beds and is responsible for a population of 87,000. Both of the hospitals belong to the Hospital District of Helsinki.
and Uusimaa and offer 24-h ER services. The ER of the health care center in Hyvinkää serves a population of 42,000 from 8 a.m. to 10 p.m. daily. The ER of Porvoo health care center is open from 4 p.m. to 10 p.m. on weekdays and from 8 a.m. to 10 p.m. on weekends. The population of Porvoo is 44,000. The study was performed in 8- or 16-h periods appropriately distributed to cover every hour of one week. These periods were spread over eight weeks from September to November 2000, avoiding public holidays. Four nurses received a 2-h training by one of the authors (OL) in collecting the samples and using the analyzer. During the study period, 755 admissions of patients over 15 years of age were recorded, 609 of whom (81%) participated in the study. Participants were inquired about their reason for coming to the ER, their alcohol usage (rate, latest dose during the previous 24 h), and smoking habits (cigarettes smoked per day, time of the last cigarette).

The breath test was performed as soon as possible after the admission. Before each assay, the measuring cell of the analyzer was spooled with ambient air, and the analysis was performed (0-sample). Ambient air contained 2-3 ppm methane. To eliminate ambient air influence on measuring low endogenous gas concentrations, the 0-sample concentrations were subtracted from the analysis results of methane.

Participants were asked to inhale deeply and then blow the entire lung volume through the analyzer's gas cell. An alveolar sample was trapped in the gas cell at the end of the expiration by closing the collecting system with a manual valve. Samples from four unconscious patients were collected by ventilating the patient via the gas cell of the analyzer with an Ambu™ squeeze bag and facemask (Figure 1). The sample was analyzed immediately.

Paired samples of exhaled breath were taken in order to minimize random error. A carbon dioxide concentration of over 3% was used as a marker of alveolar sample. Samples were accepted if the exhaled CO₂ was over 3% and the variation less than 10%. Sampling was repeated, when necessary. The sample with the highest CO₂ level was used in the final analysis. Statistics were calculated with SPSS for Windows 11.0 (SPSS Inc., Chicago, IL). The Kruskal-Wallis test was used to compare multiple groups with non-normal distribution. The Mann-Whitney U test was used to compare two groups with non-normal distribution. Analysis of variance (ANOVA) and t-test were used to compare groups with normal distribution. P < 0.05 was considered statistically significant.

The analysis results were originally expressed in ppm or vol-%. When considered necessary, they are also shown in text as mass concentration units. The conversion was made assuming that the sample temperature was 34°C and pressure 1 atm. According to our previous studies (5), the blood/breath ratio of 2466 was used to estimate blood ethanol concentrations shown in text.

The Ethical Committee of the Hospital District of Helsinki and Uusimaa approved this study. Patients or patients’ relatives (in case of unconscious patients) gave their written informed consent.

Table I. Demographics of Participants

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Hospital Centers</th>
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</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>609</td>
<td>337</td>
</tr>
<tr>
<td>Proportion of all visits</td>
<td>80.7%</td>
<td>84.0%</td>
</tr>
<tr>
<td>Median age (range)</td>
<td>44</td>
<td>(15-96)</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>(15-89)</td>
</tr>
<tr>
<td>Proportion of:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>53%</td>
<td>52%</td>
</tr>
<tr>
<td>Trauma patients</td>
<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>G-I disorder</td>
<td>12%</td>
<td>17%</td>
</tr>
<tr>
<td>Respiratory disorders</td>
<td>7.2%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Smokers</td>
<td>36%</td>
<td>33%</td>
</tr>
<tr>
<td>Heavy smokers*</td>
<td>20%</td>
<td>18%</td>
</tr>
</tbody>
</table>

* Twenty or more cigarettes per day.

Results

Patient interview

Of the patients admitted during the study period, 80.7% participated in the study. Interview data was comprehensive for 570 (94%) of the 609 participants. Patient characteristics are shown in Table I.

Sampling and analysis of exhaled breath

Sampling and analysis were successful in 589 out of 609 cases (96.7%). The 20 patients with failed samples were older than the others (median age 44 vs. 60.5 years, p < 0.01, Mann-Whitney U) and were mainly treated in hospital emergency rooms. Three of them suffered from severe dyspnoe. Samples were considered failed in 16 cases because of low exhaled carbon dioxide (< 3%, median exhaled CO₂ 2.7%). Nurses considered the sampling difficult in only two of these cases. Technical problems in computing caused the loss of data on four additional participants. Their analysis results were not recorded onto the hard drive, even though they were shown on the screen.

Difficulties in sampling appeared in some cases due to lack of patient cooperation (15 confused and 4 comatose patients). A good sample was finally obtained from all but two of these patients.

Ethanol and other solvents

The exhaled ethanol concentration exceeded the DL (1.6 ppm) in 151 patients. A patient exhaling ethanol over 25 ppm (46 µg/L), corresponding to over 0.1 g/L in blood, was classified “ethanol positive”. Fifty-four (9.5%) patients were ethanol positive—with nighttime admissions, 30% of all and 63% of trauma patients tested ethanol positive (Table II). Men were 3.7 times more often ethanol positive than women. Besides ethanol, no other intoxicating solvents were detected. One patient had used windshield washer fluid (Lasol®); he had 66 ppm (189 µg/L) of methyl ethyl ketone in addition to ethanol in exhaled breath. The measured ethanol concentrations were high: the median exhaled ethanol concentration was 435 ppm (795 µg/L), corresponding to a blood ethanol concentration of:

<table>
<thead>
<tr>
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<tr>
<td>Proportion of:</td>
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<tr>
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</tr>
<tr>
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<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>G-I disorder</td>
<td>12%</td>
<td>17%</td>
</tr>
<tr>
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<td>7.2%</td>
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</tr>
<tr>
<td>Heavy smokers*</td>
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<td>18%</td>
</tr>
</tbody>
</table>

* Twenty or more cigarettes per day.
concentration of 2.0 g/L. Distribution of exhaled ethanol concentrations is shown in Figure 3.

Carbon monoxide
The DL for carbon monoxide was 0.9 ppm. The carbon monoxide concentration of exhaled air exceeded the limit in all but five nonsmokers (Figure 4). Mean (SD) exhaled CO for smokers was 17.8 (10.9) ppm and for nonsmokers, 2.3 (1.1) ppm. Exhaled CO of more than 4 ppm (4.5 μg/L) had a positive predictive value of 0.92 and negative predictive value of 0.96 for smoking (6). The self-reported rate of smoking was 36.3% (n = 570).

Among smokers, the time from the last cigarette best explained the variation in exhaled CO (ANOVA: p < 0.01, R² = 0.23, Figure 5). The daily consumption of cigarettes only had a nonsignificant positive association with exhaled CO during the first hour after the last smoked cigarette. Among nonsmokers, men produced slightly higher CO than women (2.5 and 2.1 ppm, respectively, t-test: p < 0.01). Exhaled CO did not associate with acute respiratory disorders. No CO intoxications occurred during the study.

Methane
The distribution of measured exhaled methane (CH₄) was skewed (Figure 6). At 0.2 ppm there was a normally distributed peak, which clearly ended before 2 ppm. The proportion of patients exhaling more than 2 ppm (1.3 μg/L) of methane over the ambient air concentration (methane producers) was 31.6% (Table III). Age was the best predictor for exhaled methane. Increasing age was associated with a greater proportion of methane producers and a higher absolute exhaled methane concentration (Kruskal-Wallis test: p < 0.01, Table III). Sex, smoking, and acute gastro-intestinal disorder all became nonsignificant factors after age consideration.

Acetone
Acetone (≥ 0.7 ppm) was detected in the breath of 298 participants. The distribution of exhaled acetone concentrations is shown in Figure 7. Elevated exhaled acetone [10–76 ppm (23–175 μg/L)] was detected in 10 patients. Six of them were under the influence of alcohol and exhibited a marked alcohol dependence. The others included two depressed and suicidal patients, one elderly man found in the forest, and one boy with a sore throat.

Discussion
Despite the ability of the analyzer to detect even subtoxic levels of common solvents other than ethylene glycol, the screening of patients' exhaled breath only revealed one case of methyl ethyl ketone. A significant exhaled concentration of ethanol was a common finding, especially among male trauma patients at night.

The Gasmet FT-IR analyzer was easy to use, even for non-laboratory personnel. As a battery-operated device, it was easy to carry to the bedside. Even fragile elderly patients were able to give a satisfactory breath sample. Trained nurses also succeeded in obtaining samples from unconscious patients.

Ethanol and other solvents
Previous studies investigating the level of ethanol intoxication among patients in ER settings have mainly concentrated on trauma patients or trauma centers. In this study, 6.5% of nontrauma patients and 28% of trauma patients were ethanol positive [exhaled over 25 ppm (45 μg/L) ethanol, corresponding to a blood ethanol concentration of over 0.1 g/L]. At night, from 10 p.m. to 8 a.m., the proportions were markedly higher, 22% and 63%, respectively. Direct comparison with previous studies is difficult because of dissimilar selection of patients in various types of institutions and unequal study hours. Because of these reasons, the proportion of ethanol-positive patients in
previous studies ranges from 7.6% (county/community hospital) to 47% (university hospital trauma center) (7,8). According to the literature only 3–10% of nontrauma patients are ethanol positive (7,9). Men are more frequently under the influence of ethanol: 12.4–40.6% versus 6.6–9.9% (trauma patients) (9). This was confirmed in our study.

The ethanol concentrations of those under the influence were high. Median breath ethanol concentration corresponded to 2.0 g/L in blood. We used a blood/breath ratio of 2466, according to our previous studies with the same analyzer. This ratio leads to higher calculated blood concentrations than the 2100 generally used by the police (10). Nevertheless, the blood/breath ratio used here is more appropriate because over 30 min had apparently elapsed since the last dose, and the participants were in the postabsorptive phase.

Drinking denatured ethanol is not uncommon among Finnish alcoholics. Ethanol-containing technical products (cooker fuel or windshield washer fluid antifreeze, for example) are cheaper than legal spirits. A few percent of methyl ethyl ketone, methyl isobutyl ketone, and/or isopropanol are commonly added into these products. All these additives vaporize considerably and are easily detected in exhaled breath by the analyzer used in this study (4). In our study, however, only one patient had used denatured ethanol. In his breath analysis, methyl ethyl ketone was revealed.

Methanol is one of the most dangerous components in technical alcohol products because it is metabolized into formic acid. Incorrectly distilled spirits may contain traces of methanol as an impurity, or an alcoholic may ingest it with methanol-based windshield washer fluids. The analyzer used is

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**Figure 4.** Relative frequency polygons for exhaled carbon monoxide concentrations of nonsmokers (shaded area, n = 363) and smokers (line, n = 207). The y-axis values represent the proportion of patients in each 0.5-ppm (nonsmokers) or 4-ppm (smokers) interval.

**Figure 5.** Exhaled carbon monoxide in relation to the time elapsed from the last cigarette. Bars show means, error bars 95% confidence limits for mean (n = 140).

**Figure 6.** Histogram of exhaled methane concentrations. Main histogram: all participants, 2 ppm intervals. Small histogram: nonmethane-producing participants, 0.1 ppm intervals.

**Table III. Methane Producers* in Different Subgroups**

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Number of Patients</th>
<th>Methane Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>All successful tests</td>
<td>589</td>
<td>31.6%</td>
</tr>
<tr>
<td>Age (years) (p &lt; 0.01)*:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–30</td>
<td>139</td>
<td>18.7%</td>
</tr>
<tr>
<td>30–50</td>
<td>214</td>
<td>29.4%</td>
</tr>
<tr>
<td>50–70</td>
<td>150</td>
<td>35.3%</td>
</tr>
<tr>
<td>70–96</td>
<td>86</td>
<td>51.2%</td>
</tr>
<tr>
<td>Sex (n.s.)*:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>278</td>
<td>29.5%</td>
</tr>
<tr>
<td>Female</td>
<td>311</td>
<td>33.4%</td>
</tr>
<tr>
<td>Acute G-I Disorders (n.s.)*:</td>
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<td></td>
</tr>
<tr>
<td>Yes</td>
<td>72</td>
<td>22.2%</td>
</tr>
<tr>
<td>No</td>
<td>517</td>
<td>32.9%</td>
</tr>
<tr>
<td>Self-Reported Smoking (n.s.)*:</td>
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<td></td>
</tr>
<tr>
<td>Yes</td>
<td>207</td>
<td>25.6%</td>
</tr>
<tr>
<td>No</td>
<td>363</td>
<td>35.5%</td>
</tr>
</tbody>
</table>

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* Exhaled methane of 2 ppm.
† Kruskal-Wallis test.
‡ Mann-Whitney U test (four age subgroups tested separately).
* Exhaled methane of 2 ppm.
† Kruskal-Wallis test.
‡ Mann-Whitney U test (four age subgroups tested separately).
n.s. = nonsignificant.
sensitive enough to detect even subtoxic methanol concentrations (4). However, during this study period, no cases of methanol intoxication appeared.

**Carbon monoxide**

A number of authors have measured the concentration of CO in human exhaled breath. Clinical measurements have been possible because of new easy-to-use devices (11). Elevated exhaled CO concentrations have been mainly associated with smoking (11-13), but also with airway inflammation (14,15).

Smoking, either passive or active, is the main source of CO because inhaled tobacco smoke contains 4–5% of CO (16). Other extracorporeal sources are exhaust fumes and incomplete combustion processes. Breath CO correlates well with the blood carboxyhemoglobin level (13). Breath CO levels have been used for diagnosing CO poisoning and controlling the treatment (17), as well as for differentiating smokers from nonsmokers with quite good accuracy (11,12).

The method of sampling exhaled breath varies between studies, which leads to different exhaled CO concentrations (16,18). The most common method is to inhale deeply and hold the breath for 15–25 s prior to exhaling. The purpose is to get a more “alveolar” sample, as the carbon monoxide has time to equilibrate in the airways and blood. Even though the absolute CO concentration is smaller, an exhaled sample without breath holding leads to an equally good correlation with carboxyhemoglobin (16). The nonbreath-holding method was chosen for this study to get appropriate and equivalent samples even from noncooperative patients.

In our study, the mean CO among nonsmokers was 2.3 ppm, which corresponds to previous studies (14,15). The values for smokers varied from 1.5 to 63 ppm (mean 17.8 ppm). In the reference studies, mean exhaled CO values ranged from 17.4 to 24.5 ppm (11,12,14,15). The wide range is due to different amounts of cigarettes smoked per day and to variation of the interval between measurement and the last cigarette (18). The variation of exhaled CO in this study was best associated with the time elapsed from the last cigarette.

According to our studies, exhaled CO of over 4.0 ppm (= cut-off value) is a marker of a smoker. A literature review reveals that cutoff values vary from 4 to 10 ppm (11,12), depending on the breath sampling method, the prevalence of smoking habit in the population studied, and on the preference of optimizing either a negative or positive predictive value.

Exacerbation of asthma has been shown to raise exhaled CO to 8.4 ppm, and treatment with corticosteroids lowers it to normal levels (14). Upper respiratory tract infection (mainly influenza A) raises exhaled CO from 1.2 to 3.8–5.6 ppm (15). No association between exhaled CO and acute respiratory disorders was found in the present study. The number of patients (4 asthmatic exacerbations and 13 patients with a common cold) in this study was too limited to arrive at any conclusions on the subgroups of respiratory disorders and to discover the difference in exhaled CO.

**Methane**

Anaerobic bacteria produce methane in the large intestine. The prevalence of people excreting methane via breathing (methane producers) in this study was 31.6%. This had not been determined in a Finnish population before. The prevalence varies from 10% to 54% in the international literature (19,20). Possible factors affecting excretion status are age, sex, diet, bacterial flora, ethnic origin, and intestinal transit time. Patients suffering from gastrointestinal diseases, such as Crohn’s disease and ulcerative colitis, have been found to produce less methane than healthy controls (19). Furthermore, there may be significant intrapersonal variation in the excretion of methane because of unsteady liberation from fecal mass (21).

The distribution of exhaled methane concentrations in this study was skewed. Closer examination revealed a bell-shaped peak at 0.2 ppm belonging to the nonmethane producers (Figure 6). Because of the subtraction of ambient air methane concentrations and the variation in analysis results, the resulting concentrations were sometimes negative. Increasing age was associated with a significantly greater proportion of methane producers and a higher absolute exhaled methane concentration, which supports the findings of Le Marchand (20). Alteration in the colonic flora together with aging could, to a degree, explain the elevation (22). After considering age, there was no other significant factor to explain the variation.

**Acetone**

Acetone is produced in a normal metabolism by the decarboxylation of acetoacetate during fatty acid degradation. Predisposing factors are starvation, diabetes mellitus, and diet with low carbohydrate levels (23). Normally, healthy persons exhale less than 2 ppm of acetone (23,24). Up to 10 ppm of exhaled acetone is detected in subjects on restricted-calorie weight-loss programs (24). Fasting for 36 h raises the levels to as high as 68 ppm (157 μg/L) (23). Ketoacidosis and high acetone concentrations have been found in alcoholics with unknown causes of death (25). Except for ketoacidosis, intoxication with isopropanol or the use of technical spirits con-

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**Figure 7:** Histogram of exhaled acetone concentrations. Main histogram: all participants, 2 ppm intervals. Small histogram: low acetone concentrations, 0.1 ppm intervals. Open column: results under DL (n = 291).
taining isopropanol leads to very high blood acetone levels producing hundreds or thousands of ppms of acetone in breath (26). In this study, a total of 6 out of 10 persons with markedly elevated (over 10 ppm) breath acetone were under the influence of ethanol (123–1081 ppm, corresponding to 0.6–4.9 g/L in blood) and had an apparently strong alcohol dependence. Undernourishment most likely explains the high acetone concentrations of the two depressed suicidal patients and of the elderly man found in the forest. The young boy with the sore throat had presumably not eaten properly, either.

Conclusions

We conclude that the Gasmet FT-IR analyzer is fast and easy to use. Advantages of this method in emergency rooms are the ability to detect other solvents than ethanol and the possibility to take samples with the facemask method from unconscious patients. The adequacy of sampling can be assessed online according to the exhaled CO2 concentration. In addition to intoxicating solvents, elevated poisonous CO can also be detected. For legal and scientific purposes, it is invaluable to save the measured spectra for further investigations.

Acknowledgments

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References


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