CONTACTLESS MEASUREMENT OF BREATH ALCOHOL

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Abstract

A new approach to contactless measurement of breath alcohol is reported. The method makes use of parallel measurement of expired carbon dioxide to compensate for dilution of the expired air, assuming adequate estimation of alveolar CO_2 concentration. The results of an experimental test of the method are reported, indicating correlation between the alcohol/CO_2 signal ratio and reference measurements of blood alcohol concentration.

Introduction

Measurement of alcohol concentration in expired air is accepted as judicial evidence for drunk driving in many countries. The underlying physiological basis is the efficient gas exchange between blood and gas associated with normal lung function, believed to guarantee a close correlation between breath and blood concentrations. A remaining obstacle, however, is that the measurement requires direct access to undiluted expired air. Consequently, instruments for measuring breath alcohol are equipped with mouthpieces to guarantee that the sample gas is undiluted.

For hygienic reasons, mouthpieces for breath sampling need to be interchangeable and disposable. The handling and cost of mouthpieces are therefore significant obstacles against high volume and high throughput uses of alcohol tests and prohibitive actions. In addition, the mouthpiece offers opportunities for manipulation of the measuring result, adding to the complexity of the measuring instrument.

The problems related to mouthpieces of alcohol meters have been approached by many researchers. Devices for transcutaneous measurements have been reported, but there seems to be fundamental problems related to the permeability of skin and avoiding evaporation of the transpired fluid. Another approach favoured by suppliers of commercial instruments is to minimise the dilution of expired air by the use of funnel-shaped input ports and/or suction pumps, allowing a small but important distance to the measuring object. The capability of these devices to deliver calibrated data is, however, questionable..

In this paper, a new approach to this problem will be presented. The basic principle will be shortly outlined, along with fundamental assumptions, and limitations. The results from a first experimental test will also be reported.

Measuring principle

The measuring principle is basically to use expired CO_2 as a quantifiable marker for expired air. The underlying assumption is that the arterial and alveolar CO_2 concentration is known or predictable, whereas its concentration in ambient air is close to zero. Measurement of CO_2 in diluted expired air thus provides a measure of the degree of dilution. By measuring both alcohol and CO_2 at basically the same point, compensation is thus provided for the dilution of the expired air. As described in equation (1) below, the alveolar alcohol concentration $C_{alvEtOH}$ can be assessed from external measurements of alcohol and CO_2:

$$C_{alvEtOH} = \frac{C_{extEtOH}}{C_{extCO2}} \cdot C_{alvCO2} \qquad (1)$$

The ratio between the externally measured concentrations of alcohol and CO_2, together with the estimated value of C_{alvCO2} thus provides for the determination of the alveolar alcohol concentration.

In physiological literature, the arterial and alveolar CO_2 concentration is frequently described as 'remarkably constant' [1, 2]. Its normal numerical value in terms of partial pressure is normally 5.3 kPa (40 mm Hg), and its variability is highly limited by basic regulatory mechanisms. The level is known to increase somewhat with physical activity, and certain lung dysfunctions, such as chronic obstructive pulmonary disease (COPS).

Materials and methods

An experimental test has been performed in order to test the basic idea of the proposed method. Figure 1 shows schematically the apparatus used for the test. The apparatus included one commercial catalytic alcohol sensor (type HS130AS, Sencera Inc., Taiwan), and one electroacoustic CO2 sensor [3, 4, 5] mounted inside a small piece of Perspex tubing. Analog output signals from each of the sensors were digitised and processed using standard equipment (type NI-USB-6008, National Instruments, Inc., USA). The test data files from each recording were processed offline by standard numerical methods.

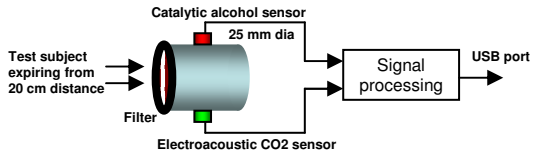

Figure 1. *Experimental setup used for testing the measuring principle.*

At each measuring instant, the test subject was instructed to blow consistently towards the sensor assembly, which was located at a distance of approximately 20 cm from the test subject's mouth region. Each measuring instant followed immediately after a measurement using a reference alcohol meter (type FST, Intoximeters, Inc., USA). Tests were performed both with the test subject before and after intake of 3 cl alcohol.

Experimental results

The results of a demonstrator experiment are summarised in the two figures below. Fig 2 shows typical sensor signals from a test subject before and after consuming 3 cl alcohol. The negative peaks of each recording coincides with the breath sample being detected by the sensors. In the sober test subject, the alcohol signal is much smaller than the CO2 signal (left part of Fig 2), whereas the opposite is observed after alcohol consumption (right part of Fig 2).

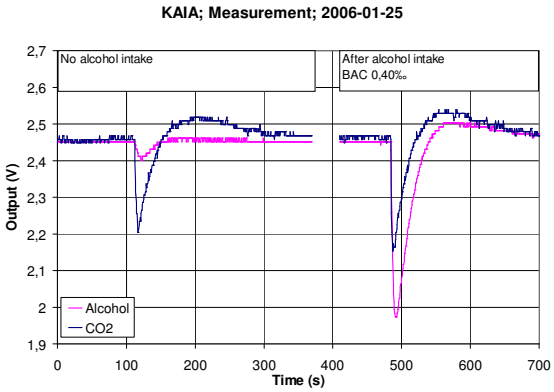

Figure 2. *Recording of output signals from the alcohol and CO_2 sensors before and after alcohol intake.*

The signal sampling rate in Fig 2 was two samples/sec. A high-pass filter with a time constant of 25 seconds accounts for the characteristic signal waveform after each breath.

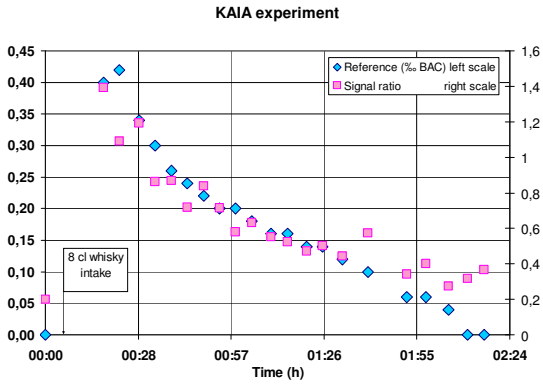

Figure 3. *Ratio between the alcohol and CO2 signal peak values before and after alcohol intake. Also plotted are measurements with a reference sensor.*

Fig 3 shows the result of determinations of the alcohol/CO_2 signal peak ratio from the experimental devices of Fig 1 at several occasions in a test subject before and after alcohol intake. Before each recording of the signal ratio, the blood alcohol concentration (BAC) was determined using the reference sensor. The observed decline of the signal ratio after intake obviously corresponds to the decline in true blood alcohol concentration.

Discussion

A new method for contactless determination of breath alcohol has been demonstrated. The method involves simultaneous measurements of alcohol and carbon dioxide at a point reached by the expired breath of the test subject.

The precision of the proposed method is, of course, depending on a number of factors related to the signal quality. Experience from initial experiments indicates that the exact distance between the sensor and the subject is not as critical as the direction of the expired airflow (very much like blowing a candle). Variations of the signal amplitude within a factor of two or even more seem to be tolerable without sacrificing precision.

Accuracy may also be influenced by systematic errors. e g emanating from the assumption of constant alveolar CO_2 concentration, or peculiarities in the sensor response.

The results of Figure 3 indicate that the proposed method is capable of resolving adequate levels of blood alcohol concentration. Further study is required for establishing actual performance and limitations.

Compared to existing techniques, the proposed method should be advantageous for its potential capability of discrimination between alcohol in the upper respiratory tract from that of blood alcohol. This discrimination is possible by comparing the time profile of the CO_2 and alcohol related signals. Another advantage is that the proposed method may be more difficult to manipulate.

Further development and design work will be required before the performance of the new method can be assessed and compared to existing techniques. Such activities are being planned in the near future.

Acknowledgements

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