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DETECTION OF ETHYLENE TRACES BY INFRARED SPECTROSCOPY IN MENTAL DISORDERS

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Abstract. Infrared (IR) spectroscopy is a relatively accurate method for detecting trace gases from the breath of people with mental disorders that could represent a general convenient screening method for the intellectual development disorder.
The objective of the activity was to estimate the risk of oxidative attack associated with ethylene breath traces in subjects with intellectual disabilities compared with healthy subjects. Because it is not possible to directly measure free radicals in the body, we approach this question by measuring the by-products that result from free radical reactions. Information was available for 15 subjects with mental disorders (in particular patients with schizophrenia). The mixture of exhaled breath in mental disorder patients contains high concentration of ethylene compared to exhaled breath of healthy subjects. Breath samples from healthy subjects and from diseased volunteer's were collected using chemically inert aluminized bags and were subsequently analyzed using IR spectroscopy.

Key words: oxidative attack, ethylene trace gas, infrared spectroscopy, mental disorder.

1. INTRODUCTION

Exhaled breath analysis is extremely attractive, because it is not only convenient and totally noninvasive, but also exhibits good patient tolerance, having no undesirable side effects [1, 2].

Real-time breath testing by simply exhaling into a sample bag would be especially useful, because the data could be immediately available to the clinician, allowing swift treatment decisions and reducing the number of visits to the clinic. Human breath is mainly composed of nitrogen, oxygen, carbon dioxide, water vapors and inert gases. In addition, thousands of volatile organic compounds (VOCs) are exhaled at very low concentrations (estimated as parts per trillion or parts per billion by volume of the exhaled breath) [1]. Part of these substances are of endogenous origin and could be characteristic for metabolic processes in the human body, while several hundred others are exogenic, that is, passing through the human body [1–3]. These VOCs are transported with the blood to the alveoli of the lung, from where they are exhaled as breath biomarkers (measurable odorants).

In this context, we utilized IR photoacoustic spectroscopy method to compare ethylene exhalations from individuals in a healthy physiological state with ethylene exhalations in a pathological state.

The results presented here have shown that there are significant differences between the composition of breath produced by patients with mental disorders and composition of breath produced by healthy subjects.

2. METHOD

The CO_2 laser-photoacoustic spectroscopy method used for the experiment presented in this study is schematically shown in Fig. 1 and the details have been published previously [4–6]. In brief, photoacoustic spectroscopy utilizes a line-tunable CO_2 laser and a photoacoustic cell, where the gas is detected. The requirement for gases to be detected with this sensitive laser instrument is that they should possess high absorption strength and a characteristic absorption pattern in the wavelength range of the CO_2 laser.

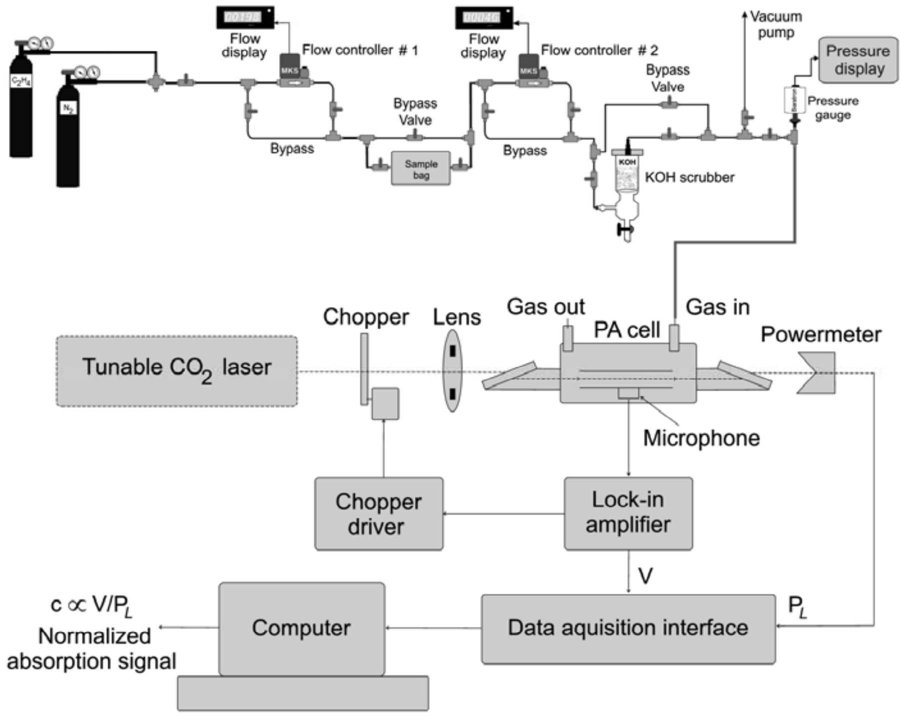

Fig. 1 – Schematic of the CO_2 laser-photoacoustic spectroscopy instrument.

Inside the detector (photoacoustic cell), traces of ethylene can absorb the laser radiation and the absorbed energy is released into heat, which creates an increase in pressure inside a closed volume. By modulating the laser beam with a mechanical chopper, pressure waves are generated and detected with four microphones with equal sensitivity around the resonance frequency and mounted in the cell wall. The photoacoustic signal was measured by a lock-in amplifier using a time constant of 1 s. The output filtered data of the lock-in amplifier were read out by a computer using a data acquisition interface with a TestPoint program, which also reads out the laser power from the power detector via a serial port, controls the chopper frequency, normalizes data and automatically stores files [4–9].

Photoacoustic technique is successfully applied in gas absorption measurements because it offers a high sensitivity that makes possible to measure absorptions coefficients on the order of 10^{-8} cm^{-1}. The laser-based photoacoustic detector is able to distinguish between different gases by making use of their wavelength-dependent fingerprint absorption characteriscs [7–9].

3. RESULTS

The measurements, which were conducted with fifteen patients with intellectual disabilities and thirteen healthy subjects, were done to evaluate the level in near real time of the ethylene gas in the exhaled breath of each subject.

The diseased subjects (6 males and 9 females, age range from 20 to 23 years) had been previously diagnosed as suffering from a psychiatric illness (like schizophrenia) and the healthy subjects without any history of psychiatric illness and non smokers, were selected as a control group (10 males and 3 females, age range from 25 to 33) and included in the study.

The subjects were asked to exhale into sample bags at a normal exhalation flow rate. To analyze the bags contents, firstly we evacuate the extra gas by the vacuum handling system, and then we flushed the system with pure nitrogen at atmospheric pressure for 30 minutes.The exhaled air sample was transferred to the cell at a controlled flow rate of 600 standard cubic centimeters per minute, and the total pressure of the gas in the detector was measured.

During the transfer of the exhaled air from the collecting bag to the cell, the sample gas was passed through a trap filled with KOH pellets to remove the CO_2 and H_2O. When this trap with a volume larger than 100 cm^3 was inserted, we found out that the signal (the response to all absorbing species at a given laser wavelength) decreased considerably, showing that the existing amounts of CO_2 and H_2O in breath can alter significantly the results, thus their removal being compulsory [6–9].

For determining the concentration of ethylene, the CO_2 laser was kept tuned at 10P(14) line where ethylene exhibit a strong and characteristic peak, corresponding to an absorption coefficient of 30.4 $cm^{-1}atm^{-1}$. The absorption coefficients of ethylene at different CO_2 laser wavelengths were precisely measured previously [4]. In this study, ethylene concentrations from breath samples in patients with mental disorders were measured and the results were compared with healthy controls using IR laser photoacoustic spectroscopy.

Figure 2 shows the average concentrations of breath ethylene for patients with mental illness, compared to the ethylene concentrations of a healthy group control. As an observation of our primary result of interest, we see that the mean ethylene level of diseased patients is more higher (75 ppb) compared to the mean ethylene level of healthy subjects (10 ppb).

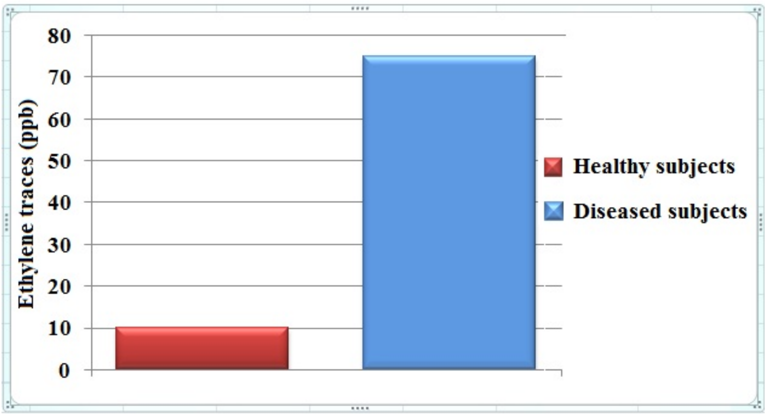

Fig. 2 – Breath average level of ethylene for 15 subjects with mental disability and 13 healthy subjects.

The goal of the study was also to explore the capacity of the IR spectroscopy technique to distinguish the subjects assumed to be with intellectual disability for the subjects assumed to be healthy.

Oxidative stress seems to be a key piece in the mental illness pathophysiology. When oxidants exceed the antioxidant defence, biological systems suffer oxidative stress, with damage to bio molecules and functional impairment.

Some contrasting results were obtained regarding oxidative attack biomarkers in diseased patients when compared with normal subjects. There is a lack of information on oxidative processes in cerebrospinal fluid and brain. It must be stressed that traces of oxidative damage may originate from various sources in the body and consequently, such a peripheral indicator may not necessarily reflect the conditions of the oxidative stress parameters in the brain [49].

Our data supports a dysregulation of energy metabolism in mental illness and suggests new markers that may contribute to a better understanding of this disease.

4. CONCLUSIONS

The present work was carried out by applying a methodology which assured better conditions to measure ethylene from exhaled breath of patients with mental disorders *vs.* healthy subjects, due to its relative simplicity, ruggedness and overall sensitivity.

The purpose of this study was to determine if ethylene biomarker from the breath of diseased patients have different levels compared with a healthy control group.

In conclusion, the data from this study support the hypothesis of the oxidant/antioxidant balance as a key component that may contribute to mental pathology.

Based on a non-invasive sampling method, stable in biological materials, and easy to measure, we conclude that IR spectroscopy analyses of breath ethylene in alveolar air appeared to distinguish patients with intellectual disabilities from non diseased controls.

The rapid development of IR CO_2 laser-photoacoustic spectroscopy and its use for gas ethylene analysis shows that this technique is promising for studying the gas absorption from the breath on the strength of its selectivity.

With improved sensitivity and specificity, CO_2 LPAS analyses of alveolar air might offer a new approach to the detection of mental disorders and better understanding of the metabolic basis of the disease.

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The authors declare that they have no conflict of interest.

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