Biomedical Applications of CO₂ Laser Photoacoustic Spectroscopy

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Abstract: - Breath biomarker analysis is an attractive field for non-invasive diagnosis of serious diseases. Collecting breath samples is preferred to direct measurement of blood samples, because it is extremely simple (in the gas phase than in a complex biological media such as blood), painless, non-invasive and contamination is easily avoided. Biomarker analysis in exhaled breath may be the most simple, rapid and safest way to accurately determine the stage or the severity of a disease. Although numerous biomarkers have been identified so far, very little is known about their origin, if they are metabolic or not (e.g. ethylene biomarker is a product of oxidative stress of linoleic acid and can assess free radical damage). Exhaled breath contains hundreds of volatile organic compounds that can be attributed to either exogenous or endogenous volatiles.

The determination of the gas compounds was investigated using a CO₂ laser photoacoustic system / CO₂ LPAS, a well known method in the field of trace gas detection, used in our study for quantitative determination of biomarkers from the breath of young adults with autism, patients with schizophrenia and patients kidney failure.

Key-Words: - biomedical applications, biomarkers, spectroscopy, autism, kidney failure, schizophrenia

1 Introduction

CO₂ LPAS is an relatively accurate and reliable method for detecting breath biomarkers from the exhaled breath of patients, that could represent an effective and convenient screening method for many diseases.

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.

In this context, we utilized CO₂ LPAS method to compare gas exhalations from individuals in a healthy physiological state with gas exhalations from patients in a pathological state (kidney failure, autism and schizophrenia disease).

2 Method and materials

The CO₂ LPAS used for the gas content measurement and presented in this report is schematically shown in figure 1 and described in detail by [3-10].

![Fig. 1 General schematic of the CO₂ LPAS instruments.](image-url)
signal was measured by a lock-in amplifier with the output filtered data 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 [3-10].

CO₂ LPAS performs well in terms of sensitive and selective detection of trace gas and it allows near on-line measurements.

The exhaled air sample was transferred to the PA cell at 600 standard cubic centimeters per minute (sccm), and the total pressure of the gas in the PA cell was measured.

4 Results

In this study, ethylene concentrations from breath samples were measured in young adults with autism, kidney failure and schizophrenia and the results were compared with healthy controls using CO₂ LPAS method.

Figure 2 shows the average concentrations of breath ethylene for subjects with autism, compared to the ethylene concentrations of a healthy group control.

As an observation of our measurements of interest, the mean ethylene level of young adults with autism was not significantly increased compared to the mean ethylene level for healthy adults.

Figure 3 show the experimental results of breath ethylene for the participants with renal failure before and after haemodialysis-HD procedure.

Exhaled breath ethylene concentrations in kidney failure at elderly patients are considerably changed immediately after the treatment (see figure 3), suggesting that subjects are under oxidative stress during HD, and ethylene may be considered a suitable biomarker for oxidative stress in this case.

Figure 4 shows the average concentrations of breath ethylene for schizophrenic patients, compared to the ethylene concentrations of a healthy group control.

The mean ethylene level of schizophrenia patients is more higher compared to the mean ethylene level of healthy subjects.

The goal of the study was also to explore the capacity of the CO₂ LPAS in biomedical applications distinguishing the subjects with various dysfunctions for the subjects assumed to be healthy.

Oxidative stress seems to be a key piece in different dysfunctions patho-physiology. When oxidants exceed the antioxidant defence, biological systems suffer oxidative stress, with damage to bio molecules and functional impairment.

5 Conclusions

The present measurements was carried out by applying a methodology which assured the better conditions to measure biomarkers from exhaled breath of young adults with autism vs. healthy subjects, patients with renal failure and patients with schizophrenia, due to its relative simplicity, ruggedness and overall sensitivity.

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

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

Based on a non-invasive sampling method, stable in biological materials, and easy to measure, we
conclude that CO₂ LPAS analyses of breath ethylene in alveolar air appeared to distinguish non-healthy patients from healthy controls.

Both the feasibility and the importance of monitoring exhaled gas from different subjects have been shown.

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