Senior Design / BS / MS Project
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AsthmaMetric

At-Home Asthma Monitor:
Combining Capnometry & Spirometry

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SENIOR DESIGN EXPO

Abstract

We addressed the need for an efficient, low-cost telemetry device for managing asthma symptoms in adults. We combined capnometry and spirometry clinical measurements into a single system to reduce the number of emergency room visits due to asthma exacerbations that are result from noncompliance to physician-established treatment plans. The results from repeated tests on healthy adults verified and validated our proposed design specifications. Therefore, our device has the potential to fulfill the market requirements for remotely improving asthma management.

Introduction

Asthma is a common chronic obstructive disorder of the airways that is characterized by recurring symptoms, airflow obstruction, bronchial hyperresponsiveness, and underlying inflammation. During asthmatic exacerbation, bronchoconstriction results in dyspnea, wheezing (high frequency, whistle-like noise auscultated during expiration), and coughing. For adults with asthma, there is an accelerated loss of lung function compared to the rate of disease progression in children. In the United States, asthma mortality was about 1.1 deaths per 100,000 in 2017 with 3564 deaths. Asthma mortality typically affects adults with 67% occurring at 45 years of age and older. The estimated annual cost of asthma in the US is roughly $56 billion in medical care and lost productivity. Nearly $12 billion are spent annually in the US for treatment and disability as a result of asthma. Roughly 9 million primary care visits and 2 million emergency room visits are a result of asthma each year in the US.

Capnography and Spirometry

Capnography is the monitoring of the concentration or partial pressure of CO_2 in respiratory gases. It has mainly been used during anesthesia and intensive care as a monitoring tool. It is usually presented as a graph of expired CO_2 plotted against time. Spirometry is the most common type of pulmonary function test. It assesses lung function by measuring the flow rate and volume of air inhaled and exhaled which makes it useful in diagnosing conditions like asthma. Some key spirometry measurements are the peak expiratory flow (PEF), forced expiratory volume (FEV), and the forced vital capacity (FVC). PEF is the maximum flow rate during a forced expiration. It is commonly used to advise patients on treatment management through medication regimen known as the asthma action plan. FEV_1 is the amount of air that can be forcefully expired in one second. A lower FEV_1 reading indicates a more significant obstruction.

Methods I Design I Analysis

The system consists of a capnography and a spirometry subsystem.

- The gas mask acquires the capnography signal. The particulate filter, water trap, and hydrophobic filter improve the quality of the signal. The SprintIR sensor measures gaseous CO2 levels by monitoring the amount of IR light passing through a filter after some of this light is absorbed by the CO2 molecules. The pump removes gas from the system.
- The flow tube and differential pressure sensor acquire the spirometry signal and measure the pressure detected upon forced expiration, respectively.
- The Arduino functions as the microcontroller, the TFT display outputs the results, and the SD Card stores the data to be sent to a physician.

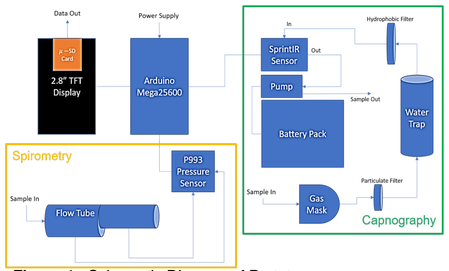

Figure 1. Schematic Diagram of Prototype

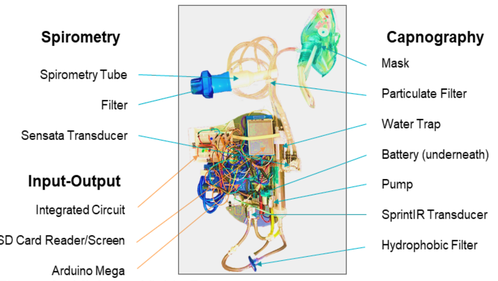

Figure 2. Minimum Viable Prototype

Results

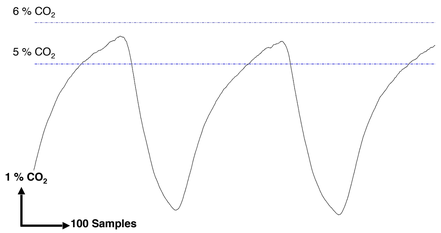

Figure 3. Recorded capnogram

Capnography

- Figure 3 shows the CO_2 waveform extracted by the peak detection algorithm implemented in MATLAB for a healthy adult.
- All peak values ($EtCO_2$ readings) fall within the expected, normal range of 5 to 6 % CO_2.

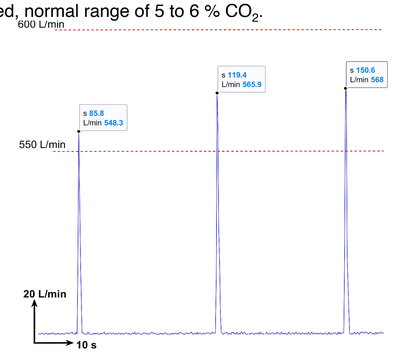

Figure 4. Recorded flow measurements (expiration phase)

Spirometry

- Figure 4 shows the PEF values recorded from a healthy individual.
- All peak values fall within the expected, normal range of 550 to 614 L/min for an adult 22 years old with a height between 5 ft and 6 ft.

Conclusion

- We have shown that a low-cost, industrial CO_2 sensor is capable of recording capnography data, as it is able to accurately measure $EtCO_2$ values.
- We have also verified that accurate PEF readings can be acquired by using an inexpensive pressure sensor.
- Through combining capnography and spirometry, our device may be used as a more reliable and convenient method to manage asthma than existing solutions.

Acknowledgments

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