Portable Capnography

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***Abstract*— Everyday there are patients who have medical emergencies involving cardiac and respiratory distress. Diagnostic equipment for pre-hospital providers is often limited in functionality due to portability of devices. There has also been a push over the last decade for emergency medical personnel to use electronic medical records due to improved patient outcome. For respiratory illnesses, capnography has proven to be very useful in both the diagnosis and treatment of patients. A capnograph is a device that graphs the change in partial pressure of CO_2 in expired air over time; the resulting graph is called a capnogram. It can be used in conjunction with vital signs to determine the effectiveness of Cardio Pulmonary Resuscitation or help diagnose a variety of respiratory illnesses. The objective of this project is to develop a portable capnograph that displays the end tidal CO_2 and wirelessly transmits the digital capnogram to a separate computer. The digital signal allows for the integration of the capnogram with electronic medical records. A small CO_2 gas sensor will be used to detect the CO_2 percentage in the expiration of a patient, while an ATmega328 microprocessor attached to a Bluetooth module will be used to process and transmit the data to a computer. Software, that is to be coded with Processing, specific to the target computer will be designed to receive and compile the data and convert it into a continuous capnogram. The device will be tested for accuracy and reproducibility over CO_2 concentrations of 0% to 20% in a CO_2/O_2 mixture.**

Keywords-capnography; electronic medical records; end tidal CO_2; respiratory

I. Introduction

As medicine continues to advance, diagnostic equipment needs to advance as well. Portable capnometers and capnographs are relatively new non-invasive medical devices that measure CO_2 in exhaled air. These devices were first used in monitoring patients under anesthesia, but are now utilized in emergency pre-hospital care. Capnometers and capnographs differ in the amount of information they display.[1] A capnograph produces a capnogram, which is a graph of the partial pressure of CO_2 over time, whereas the capnometer displays only the End Tidal CO_2 ($ETCO_2$), which is the peak of the partial pressure during each breath. A capnogram provides additional information alongside the $ETCO_2$ but there are currently no portable capnographs that are as small as capnometers.

A normal capnogram is split into four stages as seen in Fig 1. Stage I is steady state at a value of zero and occurs when only atmospheric air is present in the device. Stage II is the linear upstroke that indicates the first portion of a patient's exhaled air reaching the carbon dioxide sensor in the device. Stage III is a second linear upstroke with a much smaller slope than stage II. Stage III occurs due to partial constriction of the alveoli at the end of expiration . The final 0 stage is a quick drop that occurs due to inhalation and a return to atmospheric pCO_2. [2]

Capnography is helpful in the measurement of various respiratory issues and the immediate response to treatment. Normal values for the ETCO2 are between 35-45mmHg and variations in the value and the waveform differ with different respiratory issues. [3] The Portable Capnograph is designed to have wireless transmission through bluetooth of the capnogram to a computer, to ensure portability. Modern electrocardiogram (ECG) machines will be compatible because they are equipped with bluetooth modules, but testing will be done with a Personal Computer (PC) which allows for further analysis.

There is an International Standard for medical electrical equipment, which includes requirements for the basic safety and essential performance of respiratory gas monitors. The device will comply with aspects of ISO 80601-2-55 within the limits of the facilities available.

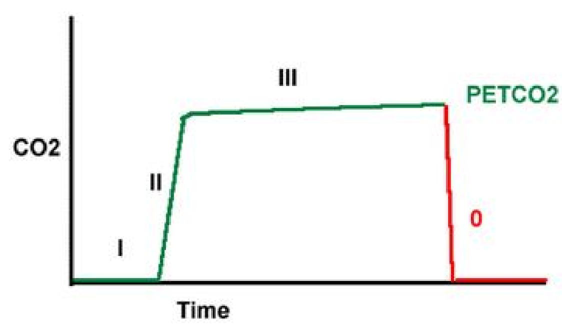

Figure 1: Sample of Normal Capnogram[2]

II. Components

The device housing is composed is to be a 2"x4"x1.5" rectangular box composed of Vero White, a 3D printer compatible material with properties similar to ABS plastic.

The housing thickness will be ⅛" uniformly, resulting in a total inner volume of 11.25 in^3. The device will be designed to be under 300 grams. It will have a luer attachment on one end for attachment of a hydrophobic filter and a bore on the other for the gas to exit the device. It will also have an additional bore on the same end as the luer attachment for connection to the airway adapter.

The airway adapter is to be capable of attachment between the mask and the bag of a conventional bag-valve-mask circuit utilized in emergency situations. The adapter will have a small nodule for collecting expired gas that will lead out of the surface of the adapter. At the exit of the collection nodule with be a luer attachment for the attachment of the hydrophobic filter. The airway adapter will ideally be composed of high density polyethelyne (HDPE) as HDPE is an easily disposed and recycled material. However, for ease of manufacturing, the prototype airway adapter may be composed of Vero White which will be 3D printed.

III. FUNCTIONALITY

A. Data Collection

CO2 percentages are measured through non-dispersive infrared absorption using the Sprint IR CO2 sensor. Samples of air will be passed through the sensor which will obtain measurements at a frequency of 20 Hz allowing for a higher precision waveform.

B. Data Display and Transmission

An Atmel ATmega328 microprocessor manages the readings made by the CO2 sensor. This data flows through two paths: display and transmission. Data is sent from the microprocessor to an LED screen where the instantaneous ETCO2 will be displayed for on-scene analysis. Data are also sent to a separate computer through Bluetooth wireless transmission for the development of a capnogram and data storage.

C. Capnogram Development and Storage

The companion program is designed to receive transmitted data from device and plot the CO2 readings versus time. A save feature will also be incorporated into the program to record patient data for future analysis by medical professionals. Data records will be saved as data points to be reproduced as a waveform when the data needs to be visualized. A print/export feature will also be added to allow for added functionality.

IV. USE OF DEVICE

Our capnograph is designed to be used in emergency settings that require the use of a bag valve mask or an endotracheal tube. An emergency responder would attach the airway adapter to the mask/tube on the appropriate end and to the bag on the other end. A hydrophobic syringe filter would be inserted into the luer attachment on the airway adapter before attaching the device to the adapter. The device could then be turned on and switched to an appropriate sampling flow rate based on the age and size of the patient. The responder(s) would be able to read the PETCO2 on the LCD display on the device and will be able to see the capnogram appear on a bluetooth-capable computing device, such as a laptop, tablet, or smartphone.

V. CONCLUSION

The intent of this project is to design a capnograph that is highly portable, versatile, and provides a means to electronically save the capnogram directly to a computer wirelessly. The portability of this design comes from the fact that it is only 12 inches cubed. This was made possible due to the fact that when the bluetooth is not on and data are not being transmitted, it is simply a capnometer. Because of this, this capnograph is optimal for emergency settings; it is portable, does not have wires, and provides a high level of detail when the user decides it is needed. It is the first capnograph that would allow viewing of electronic medical records of patient capnograms obtained from the use of capnography in an emergency setting. The device can be used in a hospital setting if necessary but is not ideal for constant monitoring since it is battery powered and will only last for 17 hours continuously

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