Background

Improper ventilation results in increased stays in the ICU, costing about $790M/Year.

Stakeholders:

- EMTs/Paramedics
- Ventilated Patient
- Emergency Department
- Researchers
- Insurance Companies
- Medical Device Company

Unmet Need

A way to eliminate wiring of current capnography technology (EtCO₂), and provide more information to EMTs in the pre-hospital setting to optimize patient care and reduce complications in transport.

Solution must:
1. Monitor EtCO₂
2. Monitor pressure and volumetric flow rate
3. Wirelessly transmit data
4. Have minimally obtrusive components

Design Specifications
1. Be compatible with the pre-hospital environment
2. Provide accurate feedback on ventilation quality
3. Display data intuitively

Existing Solutions

<table>
<thead>
<tr>
<th>Mainstream Capnography (Masimo EMMA)</th>
<th>No wiring</th>
<th>Minimal profile</th>
<th>No pressure/flow rate measurement</th>
<th>No data transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side stream Capnography (Medtronic Capnostream 35)</td>
<td>Multifunctionality/ comprehensive data display</td>
<td>No pressure/flow rate measurement</td>
<td>Obstructive components</td>
<td></td>
</tr>
<tr>
<td>Comprehensive Monitoring Unit (Stryker LIFEPAK 15)</td>
<td>Multifunctionality/ comprehensive data display</td>
<td>Compatible with other technology</td>
<td>No pressure/flow rate measurement</td>
<td>Obstructive components</td>
</tr>
</tbody>
</table>

Problem

Capnography tells first responders vital information about patients (perfusion & ventilation) and helps with intubation but can be obstructive.

Patients monitored with ETCO₂ = 790,000 in 2016
Market = $500M
Incorporated pressure and flowrate readings into a mainstream capnography device that can wirelessly transmit data.

Future:
- Incorporate device into the clinical setting
- Verify the pressure, flow rate and CO₂ concentration readings

Many thanks to UW/Harborview Emergency Department, Stryker, and to the EIH teaching team!
Prototype-IR Sensor

Software and circuit for IR sensor:
- Software/code for plotting IR sensor data completed
- Circuit to input data

Plotted EtCO2 Data: Concentration of EtCO2 [mmHg] vs. Time [seconds]

IR Detector Circuit Diagram [1]

[1] https://pyreos.com/capnography
Prototype-Pressure/Flow Rate Sensor

Differential Pressure Pneumotachometer Circuit (Winter Qtr.)

Differential Pressure Pneumotachometer Circuit (Spring Qtr.)

LabView Data Acquisition Unit

“Airway adapter” and sensor for pressure/flow rate
Flow Rate Tests

- Minimize flow resistance
- Maximize differential pressure drop
- Determine necessity of entrance length
  - Laminar flow

Flow vs. Pressure drop

Cutaway of Airway Adapter
Design
Sensor Casing:

- Houses all electronic components
- LCD screen for vital information
- Connects onto endotracheal tube via airway adapter
- Fully integrated device
C-O-You: End-Tidal CO$_2$ Monitoring

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Winter Design Review
ME/EE 498/514/498
Background: End Tidal CO$_2$

Patients monitored with ETCO$_2$ = 790,000 in 2016

Global Capnography Market = $500M in 2018
Problem 1: Inconvenient, bulky and messy

Problem 2: No real time feedback during manual ventilation

Cost of these problems = $790M/Year
## Current Solutions

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Core Functions</th>
<th>Measures CO₂ in Patients’ Exhaled Breath</th>
<th>Monitors Pressure and Flow Rate</th>
<th>Wirelessly Transmits Data</th>
<th>Minimally Obtrusive Components</th>
<th>Collects/Stores Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masimo EMMA</td>
<td></td>
<td>✓</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<tr>
<td>Medtronic Capnostream 35</td>
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<tr>
<td>Stryker LIFEPAK 15</td>
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</table>
A way to eliminate wiring of current capnography technology (EtCO2), and provide more information to EMTs in the pre-hospital setting to optimize patient care and reduce complications in transport.
Core Functions

Monitors CO₂, Pressure, and Volumetric Flow Rate

Monitors EtCO₂ Accurately to Within Industry Standards

Minimally Obtrusive Components

Wireless Transmits Data

Collects/Stores Measurements
Design Concept

Monitors EtCO2 Accurately to Within Industry Standards

Minimally Obtrusive Components

Wireless Transmits Data

Monitors Pressure and Volumetric Flow Rate

Collects/Stores Measurements
Design Concept

1. Mainstream EtCO₂ Monitoring
   IR Spectroscopy of Breath

2. Real Time Bluetooth Data Transmission
   Bluetooth component integration

3. Pressure and Flowrate Measurements
   Novel incorporation of sensors
End-Tidal Carbon Dioxide Monitoring Device
Prototype-IR Sensor

Software and circuit for IR sensor:
- Software/code for plotting IR sensor data completed
- Circuit to input data

Plotted EtCO2 Data: Concentration of EtCO2 [mmHg] vs. Time [seconds]

IR Detector Circuit

IR Detector Circuit Diagram [1]

[1] https://pyreos.com/capnography
Prototype-Mechanical Aspects

Sensor Casing:
- Houses all electronic components
- LCD screen for vital information
- Connects onto endotracheal tube via airway adapter
- Fully integrated device
Prototype-Pressure/Flow Rate Sensor

Differential Pressure Pneumotachometer Circuit (Winter Qtr.)
Differential Pressure Pneumotachometer Circuit (Spring Qtr.)
LabView Data Acquisition Unit
“Airway adapter” and sensor for pressure/flow rate
Testing: LabView Pressure/Flow Rate

Pressure vs Time (Exhaled)

Ideal Range: 0-15 psi
Our Results: 0-4 psi

Flow Rate vs Time (several breaths)

Ideal Range: 400-700 L/min
Our Results: 0-10 L/min
LabView (cont.)

(Uncalibrated) Flow vs Volume Loop

Ideal Flow vs Volume loop
Flow Rate Tests

- Minimize flow resistance
- Maximize differential pressure drop
- Determine necessity of entrance length
  - Laminar flow

Flow vs. Pressure drop

Cutaway of Airway Adapter Design
Other/Future Testing

Other completed Testing:
- IR detector data and plotting
  - Q: Can our code plot data from the CO$_2$ sensor?
  - T: Input data into code and see if it can plot the proper waveforms
- Sensor casing shape/size
  - Q: Is the form factor too big to be mounted mainstream?
  - T: 3D printed preliminary design and tested fit on airway adapter

Testing in the near future:
- Bluetooth
  - Q: Can the data from all the sensors be integrated into the TI/Arduino microcontrollers and be transmitted to an LCD/Laptop wirelessly?
  - T: Use microcontroller serial data reader to plot refined data and use HC-05 to transmit to laptop/phone/LCD
- Integrated weight and form factor
  - Q: Does the integrated device weigh less than 150 grams?
  - Q: Does the form factor obstruct EMS personnel in the working environment?
  - T: After integrating, check in with clinical partners and get a qualitative gauge for size and shape
- Airway Adapter Design
  - Q: Does the design allow for accurate pressure/flow rate measurements?
  - T: Run FEA simulations to check for fully developed and laminar flow

Plot: CO$_2$ (concentration) [mmHg] vs Time [seconds]
Updated Milestones

PARTS LIST:
1. Sensor Casing
2. Airway adaptor
3. LCD Screen
4. CO\textsubscript{2} Capnography Sensor
   a. Infrared Detectors Dual CO\textsubscript{2} Sensor
   b. IR Emitter
5. Differential Pressure Sensor
6. Flow rate sensor
7. A23 battery
8. PCB control board
9. Bluetooth module
10. Wiring

MILESTONES:
1. Test the individual components 6/2 (continuous)
2. Validate our design with clinicians 6/10
   a. Incorporate device into the clinical setting
   b. Verify the pressure, flow rate and CO\textsubscript{2} concentration readings
Summary and Future Work
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