



Nebulized Drug Delivery using Continuous Positive Airway Pressure Device



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Problem Statement

A method is needed for automated delivery of respiratory bronchodilator medications, like albuterol, to patients as they use the CPAP device.

Background

Sleep Apnea

- Occurs when the trachea of the subject closes during sleep, repeatedly waking the subject and causing chronic sleep deprivation
- Affects over 12 million Americans
- Continuous Positive Airway Pressure (CPAP) Devices
- Include a pressure source, such as a blower, a circuit, and tubing to a mask worn by a patient.
- Provide positive pressure to assist in patient breathing.
- Used during sleep or in ambulatory situations for patients with sleep apnea or asthma.

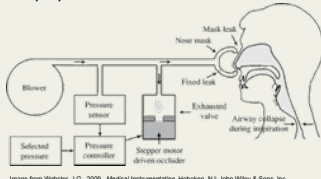


Image from Webster, J.G. 2009. Medical Instrumentation. Hoboken, NJ: John Wiley & Sons, Inc.

Nebulizers

- Aerosolize liquid medication into a mist of many very small liquid droplets.
- Often used with albuterol sulfate, a bronchodilator.

Jet Nebulizer

- Uses pressurized air
- Efficiency ~ 39±3%**

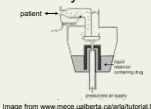


Image from www.mccc.uabeta.ca/air/nebulizer.htm

Ultrasonic Nebulizer

- Uses ultrasonic waves
- Efficiency ~ 86±5%**

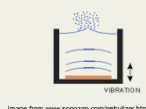
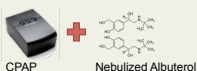


Image from www.sonozap.com/nebulizer.htm

Design Specifications

The drug delivery device should:

- Deliver aerosolized medication within the CPAP circuit.
- Be compatible with any CPAP device currently on the market.
- Be capable of daily use, for at least 8 h at a time.
- Deliver up to 9 mL of medication, such as albuterol sulfate, during usage.
- Allow the user to sleep comfortably and safely during use.
- Include a user-programmable feature to specify dosage and delivery timing.



Client: Dr. Mihai Teodorescu, MD¹

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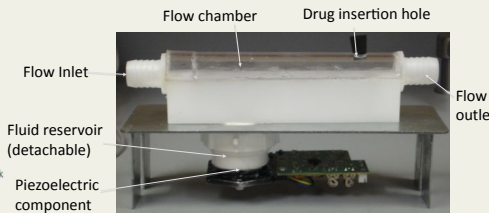
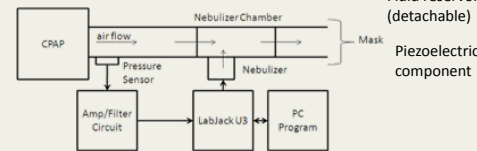
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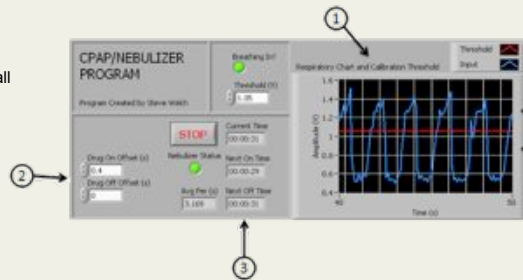
Final Design

Overall Design (below)

- Nebulizer injects drug directly into CPAP line
- Pressure sensor and program control nebulizer



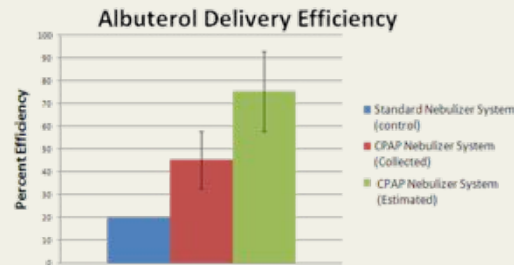
Ultrasonic Nebulizer (above)
• Uses high-frequency piezoelectric crystal to aerosolize drug for patient delivery



Program (left)

- Pressure sensor output (blue line) and threshold voltage (red line) distinguishes when subject is inhaling/exhaling
- Timing inputs allow user to increase/decrease amount of drug delivered per respiratory cycle
- Timing outputs and nebulizer status indicate program vitals in real time

Testing



Efficiency Testing Results (left)

- Control (blue bar) is from drug manufacturer's testing
- Difference between measured efficiency (red bar) and control is statistically significant ($p < .05$)
- Estimated efficiency (green bar) is the predicted efficiency of a fully optimized system

Budget

Item	Vendor	Purpose	Unit Cost	Cost
Total from last semester	Various	Used to develop effective prototype designs	\$159.61	\$224.68
HDPE Plastic block	McMaster	Machined into nebulizer reservoir base	\$3.00	\$12.00
Polycarbonate tube	McMaster	Cut and epoxy to form nebulizer chamber	\$2.19	\$17.53
Tubing and adaptors	ACE Hardware	Non-corrugated substitute for CPAP tubing and adaptors to connect to nebulizer	\$13.06	\$13.06
Plumbing kit	ACE Hardware	Fix to nebulizer making reservoir removable	\$5.26	\$5.26
PTFE Sheet	McMaster	Promote hydrophobic inner surfaces of nebulizer chamber	\$3.00	\$22.10
CPAP unit	UW-Hospital	Used to test feasibility of prototype ideas	\$0	Donated
Albuterol Nebulizer Doses	UW-Hospital	Used to test feasibility of prototype ideas	\$0	Donated
Total from this semester			\$26.51	\$69.95
Total overall			\$186.12	\$294.63

Future Work

- Improve ease of use of device. Modifications include:
 - Hinged top to nebulizer reservoir
 - Improve ease of sterilization
 - Improve graphical user interface
- Submit Invention Disclosure and obtain patent protection
- Complete testing protocol and obtain IRB approval
- Conduct "Stage I" clinical trials in Dr. Teodorescu's sleep research lab.

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