Sleep Apnea Therapy Device

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Abstract

Sleep Apnea is a sleep disorder in which natural breathing is interrupted causing frequent waking. This frequent waking caused by apnea prevents a person from reaching deep sleep leaving them tired throughout the day. It affects more than 20 million Americans and is a contributing cause of high blood pressure, weight gain, and stroke. Our design focuses on the treatment of Central Sleep Apnea (CSA), which is characterized by intermittent disruptions in the autonomic nervous system that controls breathing. There are few treatment methods that only treat CSA, many of which are rejected by users, which drives the need for an effective and comfortable treatment. Our design incorporates a variable dead space method as well as a rotational motor to effectively treat sleep apnea. Increasing re-breathed CO_2 levels through dead space variation reduces the occurrence of apneas and stabilizes breathing. By inducing mild hypercapnia, ventilatory stimulation is increased and the symptoms of CSA are reduced.

Motivation

- Current treatment is a continuous positive airway pressure (CPAP) machine
- Problems with current treatments
  - 50% user rejection rate [1]
  - Primarily focused Obstructive Sleep Apnea (OSA) [1]
  - Needs to be plugged into a wall
  - Bulky/ heavy
  - Causes complications such as nasal congestion, dry mouth, headaches, and continued tiredness [1]

Background

- Sleep apnea- An inability to reach deep sleep caused by frequent interruptions in breathing [6]
- Affects roughly 10% of the US population [6]
- 3 Primary types
  - OSA (Obstructive sleep apnea) [3]
  - CSA (Central sleep apnea)[3]
  - Combination [3]
- Anatomical Dead Space
  - The area in the trachea, bronchi, and air passages containing air that does not reach the alveoli during inspiration and is not involved in gas exchange [2]

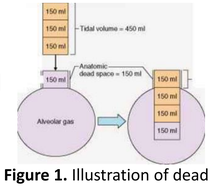

Figure 1. Illustration of dead space. [5]

Design Criteria

- Lightweight (under 1 kg)
- Compact (80mm diameter and 200mm length) and circular
- Comfortable application of mask to the face and device to the chest
- Battery Operated
- Durable (3-4 months for 8-10 hours per day)

Final Design

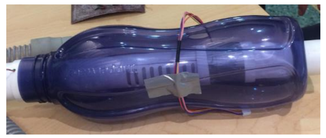

Figure 2. A hard waterbottle with PVC pipe through it was used as the body of the device. The PVC pipe has slits cut into it to vary dead space volume

Figure 3. The flow sensor is secured in the PVC pipe inside the body of the device.

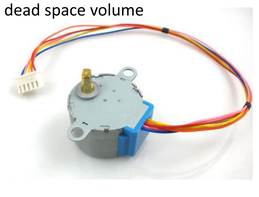

Figure 4. A stepper motor is secured at the end of the PVC pipe. It is connected to a cover slide that rotates to cover or uncover slits cut in the PVC pipe.

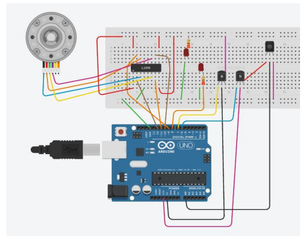

Figure 5. A schematic of the circuit that controls the stepper motor based on the readings from the flow sensor.

- A mask and tubing are connected to the PVC pipe
- The user breathes through the mask and the breathed air travels through the tubing to the flow sensor which sends an analog signal to the Arduino
- When apnea is detected, the slits are uncovered via the stepper motor inducing mild hypercapnia

Airflow Sensor and Apnea Detection

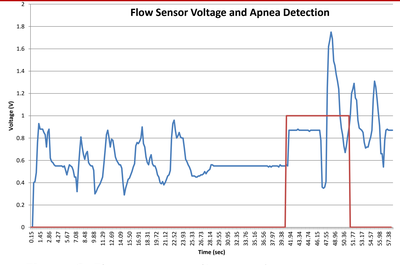

Figure 6. Flow sensor voltage and apnea detection data. The red line represents when apnea was detected and the blue line represents the breathing pattern of the test subject. Testing verified the functionality of the algorithm.

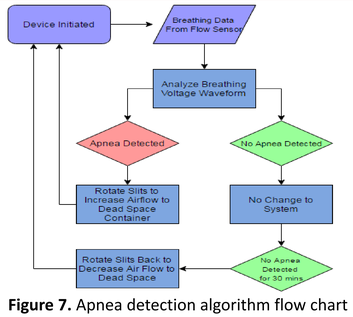

Figure 7. Apnea detection algorithm flow chart that drives the device as an dynamic and active apnea therapy system

Comfort Testing

- Convenience sample of 30 taken
- Ages ranged from 20-23

Figure 8. Test subjects answered questions on a scale of 1-5 with 1 being unbearable and 5 being hardly noticeable.

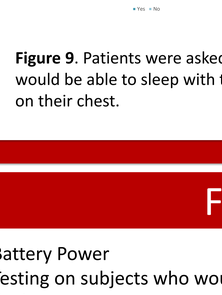

Figure 9. Patients were asked if they would be able to sleep with the bottle on their chest.

- Comments during testing were usually the mask was too tight or did not seal completely

Future Work

- Battery Power
- Testing on subjects who would be in the demographic for those using the device
- Condense into a smaller device
- New circuit housing and printed circuit board (PCB)

Acknowledgements

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References

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