Teaching Model for Ventilation and Perfusion Mismatching

Team Members: Brittany Glaeser, Kaitlin Lacy, Zoe Schmanski, Jenna Eizadi
Client: Dr. Christopher Green
Advisor: Dr. Amit Nimunkar

Abstract

Ventilation-perfusion (V/Q) mismatching describes the ratio between the air that reaches the alveoli of the respiratory system and the passage of fluid through the the capillary beds surrounding the alveoli, which exchange gases between them. The use of LED lights was chosen to depict V/Q ratios on a 3D printed base model of a single alveolus and a single capillary. Testing was completed by administering a survey to two different populations, medical students and non-medical students, to determine whether or not the model aided in learning about V/Q mismatching. Future work includes completing a final print with a larger back compartment, consolidating the circuit, expanded testing with more medical students, and incorporating the ability to represent infinite V/Q ratios.

Motivation

Ventilation and Perfusion mismatching can be a difficult concept for medical students to visualize, specifically, how it can lead to dead space ventilation and hypoxemia. An interactive model is needed to help the medical students conceptualize the different ventilation perfusion ratios and their consequences.

Background

- Alveolar Ventilation [L/min] - volume of inhaled air that reaches the alveoli per minute [1]
- Perfusion [L/min] - passage of fluid through capillary bed surrounding alveoli [1]
- Ventilation perfusion (V/Q) ratio
  - Desired ratio 1:1
  - Mismatching occurs when ratio is not 1:1 and can lead to hypoxemia [2]
  - Diseases like asthma, COPD, cystic fibrosis, lung diseases and pulmonary hypertension can cause mistaching [3]
- The extremes include:
  - High V/Q: Dead space ventilation - no blood flow [4]
  - Low V/Q: Shunt - no ventilation [4]

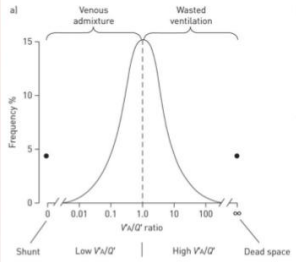

Figure 1: Graphical representation of different V/Q ratios [5]

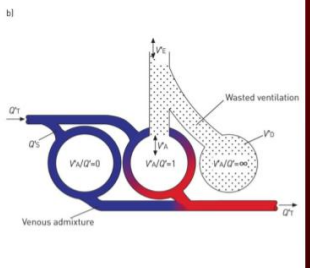

Figure 2: Visual representation of normal V/Q versus dead space [5].

Specifications

- Model ventilation and perfusion mismatching
- Includes an interactive component to display five important V/Q ratios
  - Can be used multiple times
  - Easy setup
- Visible to a lecture hall of 180 people with use of a document camera; no larger than 22cm x 27cm
- Less than 6.8 kg for easy portability and storage
- Withstand long periods of time in storage
  - Service life of 5 years
- Include interactive component to alter V/Q ratios

Materials

- 3D Printed PLA
- Arduino Nano
- Adafruit Neopixel 5050 RGB Rings
- Adafruit Neopixel LED Stirp
- Momentary Push Buttons
- Adafruit 1.44'' TFT LCD Display
- Shrink Plastic Sheets

Total Cost: $127.56

Final Design

Figure 3: Model representation of Shunt, 1:1 ratio, and dead space ventilation

Features

- 3D printed base modeling a single alveolus and capillary
- Concentric LED rings placed in alveolus representing intake and diffusion of oxygen into the bloodstream
- LED strip with color gradient that flows from blue to purple to red representing oxygenation of blood
- 4 buttons that increase or decrease the ventilation or perfusion rates
- LCD screen displaying alveolar ventilation and blood flow rates, along with the resulting V/Q ratio

Figure 4: Model representation of air flow through alveolus

Testing & Results

- Analysis of model's capability to improve on a subject's understanding
- Google Form with pre-recorded videos of teaching model and corresponding multiple-choice questions to assess differences in V/P rates and different V/P ratios with physiological implications
- Population #1: 46 subjects without previous knowledge
- Population #2: 5 medical students with knowledge of V/P mismatching
- Test #1: T-Test on Population #1 Mean Score
  - Baseline score of 33.33% corresponds to selecting answers at random
- Test #2: T-Test on Population #2 Mean Score
  - Expect score of 100% given aid from the teaching model
- Test #3: Two-Sample T-Test comparing Populations #1 and #2

Test Number	Null Hypothesis	Alternative Hypothesis	Mean Score	Standard Deviation	P-Value
1	$\mu = 0.333$	$\mu > 0.333$	0.7935	0.073	$4.48*10^{-9}$
2	$\mu = 1$	$\mu < 1$	0.98	0.06	0.17
3	$\mu_1 = \mu_2$	$\mu_1 < \mu_2$			$7.25*10^{-4}$

Discussion

The device improves existing knowledge of medical students, leading them to achieve full understanding of V/Q ratios. In the general population, the model also improved the subjects' understanding of V/Q ratios, but a variation in the mean suggests full understanding was not achieved. Comparing the two population means, it can also be concluded that prior knowledge on V/Q mismatching increases the effectiveness of the teaching model.

Future Work

- Final print for client
- Clean up and better secure circuit
- Infinite Ratios
- Further testing
  - Increase the population of medical student responses
  - Test improvement with multiple questionnaires

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References

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