Esophageal Simulator

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Abstract

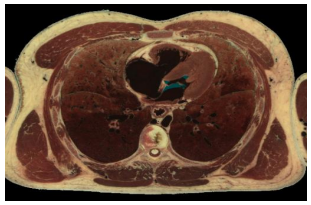
Currently, Eso-technologies is developing a new cardiac monitoring system designed to read pressures within the esophagus. This device is intended to the Pulmonary Artery Catheter (PAC). Testing and development of the new device is limited to a specific number of clinical trials set by the FDA.

Eso-technologies has asked our team to design an esophageal simulator that will enable the device to be tested without the need for human patients. This will allow for more testing and quicker refinement turnaround.

Background

Eso-Technologies Device
- New device designed to replace the Pulmonary Artery Catheter (PAC) which monitors heart function from within the pulmonary vein.
- New device is designed to monitor heart function via the esophagus.
- Pressure sensor designed with two saline filled balloons: reference balloon and recording balloon.
- Recording balloon will rest directly behind the left atrium and record atrial, lung and esophageal pressure.
- Reference balloon will rest higher up in the esophagus and record lung and peristalsis pressure.
- Recording balloon – Reference balloon = left atrial pressure

Anatomy
- Esophagus is positioned in front of the trachea and just behind the heart
- Pressures are translated from the atrium into the esophagus through the atrial and esophageal walls.
- Chest cavity is a closed system and any change in volume due to respiration changes the pressure in the system. These pressure changes are felt within the esophagus.



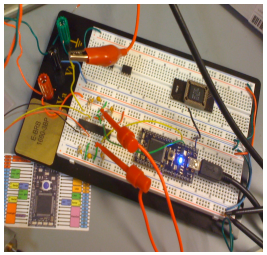
An image including the esophagus, heart and lungs (1)

Design Criteria

Pressure Waveforms
- Generated waveforms must mimic the pressures of the heart, lungs, and esophagus
- Cardiac ~ 0-30 mmHg @ 40-140 beats/min
- Lungs ~ 0-40 cmH20 @ 0-20 breaths/min
- Peristalsis ~ 0-50 mmHg @ 1-10 contractions/min
- Computer program must be easily adjustable to mimic extreme conditions

Esophagus Device
- Device must be able to incorporate both balloons

Final Design



Motor Control System

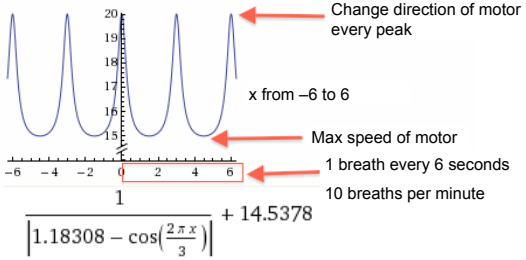
Motor Control
- 30V Biopolor Stepper Motor
- LPC1768 mbed Microcontroller programmed using C++ computer code language
- L6219 Driver
- C++ code is sent from computer to microprocessor then to controller where it is translated into an output signal that controls the stepper motor

Bipolar Stepper Motor (3)

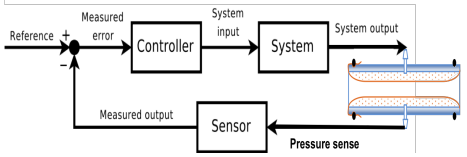
Esophagus System
- PVC pipe (2.5in long; Do = 1.25in; Di = 1in)
- Penrose drain
- O-ring and pipe clamps
- Glass syringe (ideal: 10+ cc all glass)
- Sphygmomanometer
- Gear system with 48 pitch gear and rack
- Gear system translates the rotational movement of the stepper motor into linear motion which pushes and pulls the plunger of the syringe
- Plunger movements increase/decrease pressures within the flexible membrane
- Pressure changes fluctuate the flexible membrane which impinges upon cardiac monitor
- Pressure transducer is used for testing and allows us to monitor the pressures being created within the system

Esophageal Simulator System

Programming



Future Work



Future improvement to the device include:
- Increased speed and accuracy of motor to include atrial pressure waves.
- Improved pressure sensing system to provide feedback and make necessary adjustments automatically.
- Add complexity to program to include more pressure options and variations.
- Additional analysis on the effect of balloon volume changes and pressure readout.

Sample Waveforms Ideally Generated

Note in upper trace the sinusoidal oscillations that are present. This is representative of the respiratory cycle.

References

1. *Visible Human Server*. Web. 13 Oct. 2010. <http://visiblehuman.epfl.ch/>.
2. Widmaier, Eric P., Hershel Raff, and Kevin T. Strang. Vander's Human Physiology: the Mechanisms of Body Function. Boston: McGraw-Hill, 2006. Print.
3. http://www.cecs.csulb.edu/~hill/ee347/Bipolar_Stepper_Motor_Lab/images/djvnr2b_85dxjvr5gk_b.jpg

Acknowledgements
- Dennis Bahr, Ph.D
- Chris Reikersdorfer
- Elena Bezrukova
- Amit Nimunkar
- Peter Klomberg