HeartMe Cardiac Simulator

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Inspiration: By day, I am a cardiovascular surgery nurse and by night I am an electronics learner and tinkerer. I decided to combine both of my loves into one project – a cardiac simulator. It is my hope that it will become a good resource for both healthcare givers as well as patients. Healthcare givers can use the cardiac simulator as an inexpensive learning tool and patients can use the cardiac simulator to better understand and visualize their conditions.

Use of Microcontroller: The project's peripherals rely solely on the Parallax Propeller microcontroller for direction and function. Propeller code is used to initiate and define rhythm parameters, respond to switches, drive the LCD, pulse generator, HR receiver and audio simulator.

Innovation: Most physical cardiac simulators that healthcare providers work with are heavy, bulky, and prohibitively expensive. They usually lack mobility and require an extensive system of electronics to function (Zoll Defibrillator for visualization, dummy with pulsatile points or sound generator with customized stethoscopes for audio simulation). Each component unnecessarily costs in the hundreds or thousands. The cardiac simulation I have created costs less than 50 dollars, is mobile, and is capable of simulating the electrical activity, auscultated audio, and palpated pulse of 17 different rhythms, and even interface with the Polar heart rate receiver, reflecting basic cardiac activity of the user.

There are three main aspects to this training tool:

Visualization:

The LEDs on the heart board represent the sinoatrial node (and occasionally the atria), atrioventricular node, and bundle branches. This serves as a useful learning and demonstration tool for patients and healthcare providers as to what the various regions of electrical activity, in the heart, are doing during specific rhythms. To students, it makes more sense to first understand the physiological origins of electrical activity rather than analyze foreign waveforms. Once they have a good grasp of what the cardiac conduction system is doing physically, ECGs then make a great deal more sense. Students can begin thinking about why the measurements made on ECGs are indicative of impaired electrical activity in specific locations, and why those are important. This deeper understanding enables healthcare providers to properly discuss certain conditions with their patients.

For example, I explain atrial fibrillation in the following manner:

"The heart has four chambers, two on the top, and two on the bottom. One of the chambers on the top is like the conductor of an orchestra. It decides what beat the rest of the heart will go at. If it says beat, the rest of the heart beats. Occasionally, the orchestra, or these two chambers, will say, 'We want to be the boss' and start sending many signals to the lower chambers. The lower chambers then try to keep up with all of the signals it's receiving. This often leads to irregular and higher heart rates – even as high as 160s. This is sometimes a temporary side effect of heart surgery because of the stress of the surgery and because of inflammation from the surgery." Long story made short: patients don't want to know what's happening on their ECG, they want to know what it means for them and their bodies. As healthcare providers, it is up to us to explain it in an understandable manner.

Palpation:

Some may not see this as a useful training tool without an ECG visual, and diagnostically, it is true that an ECG provides a wealth of information. However, the ability to discern a rhythm through only auscultation and palpation should absolutely not be underestimated.

The palpation simulation is achieved through use of a solenoid valve and plate. When the solenoid valve turns on, the plate is magnetically attracted to the valve. With short, controlled, and repetitive bursts of signal sent to the solenoid valve, we simulate a pulse. The additional benefit of a valve and plate is that it is very easy to overpower the plate, and lose the pulse sensation. This simulator trains a user how to use a delicate touch. On a real body, a patient's pulse may easily be obliterated with too strong of a force, and often requires a light but steady touch.

Without the presence of ECG monitors, healthcare providers need to be able to use their other senses to examine whether the patient is in a healthy state or in a situation that needs addressing. For example, through a simple pulse assessment of an unresponsive person, a healthcare provider can tell the rough blood pressure of a person:

- If the patient's pedal pulse is present, patient has a systolic blood pressure of at least 90 mm Hg
- If the patient has no pedal pulse, attempt to find the radial pulse – if present, patient has a systolic blood pressure of at least 80 mm Hg
- If the patient has no radial pulse, attempt to find the femoral pulse – if present, patient has a systolic blood pressure of at least 70 mm Hg
- If the patient has no femoral pulse, attempt to find the carotid pulse – if present, the patient has a systolic blood pressure of at least 60 mm Hg.

Auscultation:

Through the use of Audacity, I created a small audio sample that would be played at certain intervals during a given rhythm. A user can connect headphones via the audio jack and hear what the rhythm would sound like.

Through auscultation, it is also possible to ascertain whether a patient's rhythm is of sinus origin or if the patient has a rhythm like atrial fibrillation. Without the use of ECG monitors, a carefully trained ear is capable of determining a course of treatment for a patient. For example, if a medic is auscultating a patient and hears fast irregularity, we can assume the patient is at risk for clots. Unless properly treated, the condition could lead to stroke, pulmonary embolism, and deep venous thromboembolism. So we would anticipate treating the patient with antiarrhythmic medications, blood thinners, and of course acquire an ECG to see what the specific rhythm is.

The rhythms covered are:
Normal Sinus Rhythm
Sinus Bradycardia
Sinus Tachycardia
Atrial Fibrillation
Atrial Flutter
Supraventricular Tachycardia
Ventricular Fibrillation
Ventricular Tachycardia
Sinus Rhythm with a 1st degree atrioventricular block

Sinus Rhythm with a 2nd degree atrioventricular block Type 1
Sinus Rhythm with a 2nd degree atrioventricular block Type 2
Third degree atrioventricular block
Sinus Rhythm with a Bundle Branch Block
Junctional Rhythm
Idioventricular Rhythm
Normal Sinus Rhythm with Pre-Atrial Contractions
Normal Sinus Rhythm with Pre-Ventricular Contractions
Polar Heart Rate Receiver Rhythm

Videos:

- https://www.youtube.com/watch?v=VLxsLt2oI4A
- And to see the LEDs brighter: https://www.youtube.com/watch?v=hl7d6Jklkxw