REUTILIZATION OF NONINVASIVE INSTRUMENTS FOR SYSTEMIC CARDIOVASCULAR ANALYSIS

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ABSTRACT

Systemic vascular impedance is a mathematically derived spectrum that indicates opposition to pulsatile blood flow. Impedance cannot be directly measured; rather, it is calculated using data from pulsatile waveforms and blood volume flow waveforms. Three years ago, Dr. Nancy Sweitzer conducted research on impedance to blood flow using tonometry and blood flow equipment. The owner of the leftover equipment, Dr. Naomi Chesler, has tasked this team with reassembling the instruments with the ultimate goal of measuring impedance data in healthy individuals. In the process of reassembly, it is the team's task to take inventory of which devices work and which do not, which devices have missing or incomplete parts, and which instruments can be reutilized for further use in future research.

PROBLEM STATEMENT

Problem Statement

To reutilize and repair the instruments used by Dr. Sweitzer and to determine if and how the instruments can measure impedance.

Motivation

- Ventricular failure is the number cause of death in people with cardiovascular disease[1]
- Vascular impedance is traditionally measured invasively, and therefore is a costly and risky procedure that is not often measured in humans[2]

BACKGROUND

Dr. Sweitzer's research centered around investigating the efficacy of various biomarkers as predictors of cardiovascular health as well as the effects of cardiovascular drugs on those biomarkers. Researchers in the field laud impedance as a much more descriptive measurement than systemic vascular resistance[2]. The Windkessel model, defined by Otto Frank in 1899[4], represents the cardiovascular system as an electrical circuit consisting of a resistor and capacitor in parallel, accounting for the observed pressure wave form. Many researchers have elaborated this model to include more components that explain various physiological phenomena. Shown in Figure (1) is a four component modified-Windkessel model. Systemic vascular impedance can be taken as the equivalent impedance of these components, though only as an estimate.

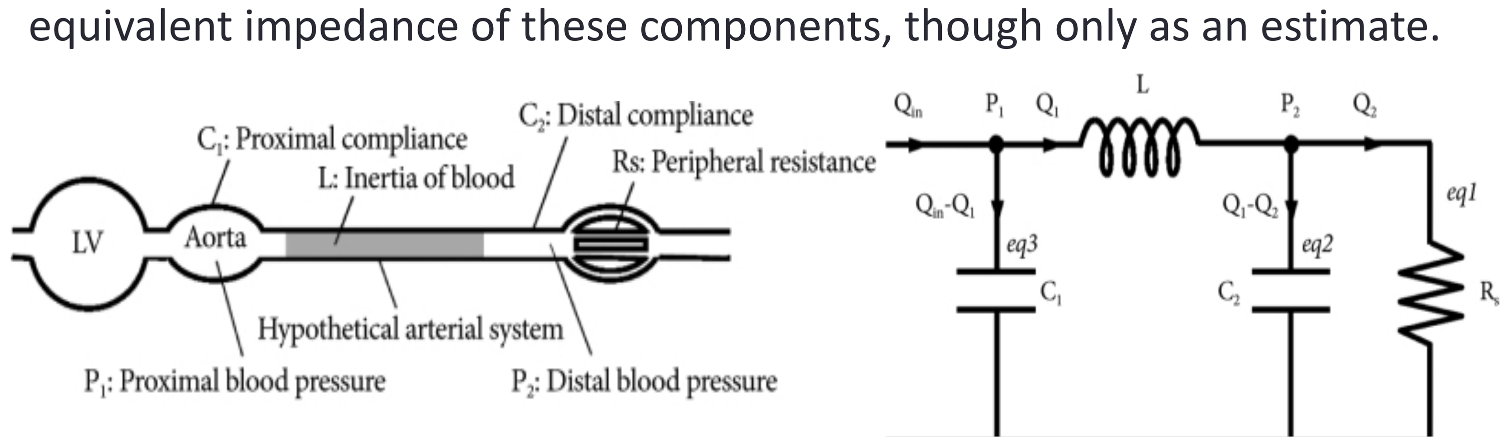

Figure (1). The Windkessel model uses an electrical circuit as an analogy for the systemic vascular system

IMPEDANCE CALCULATION

Systemic Vascular Impedance/Aortic Input Impedance[2]

- Total impedance of the systemic vascular system
- Necessary measurements
  - Pulse Pressure Waveforms from carotid and brachial arteries
  - Sphygmomanometric values from brachial artery
  - Doppler flow waveform from Left Ventricular Outflow Tract (LVOT)
  - Electrocardiogram

$$Z_{in}(n) = \frac{M_p(n)}{M_f(n)}\ ;\ \phi_z(n) = \phi_{p(n)} - \phi_{f(n)}$$

harmonics $n = 0, 1, 2, 3, \ldots$

Characteristic Impedance[3]

- Impedance characteristic of a specific vessel
- Necessary measurements
  - Pulse pressure waveform
  - Applanation pressure
  - Doppler flow waveform

$$Z_c = A \cdot \frac{dP}{du}$$

RESULTS

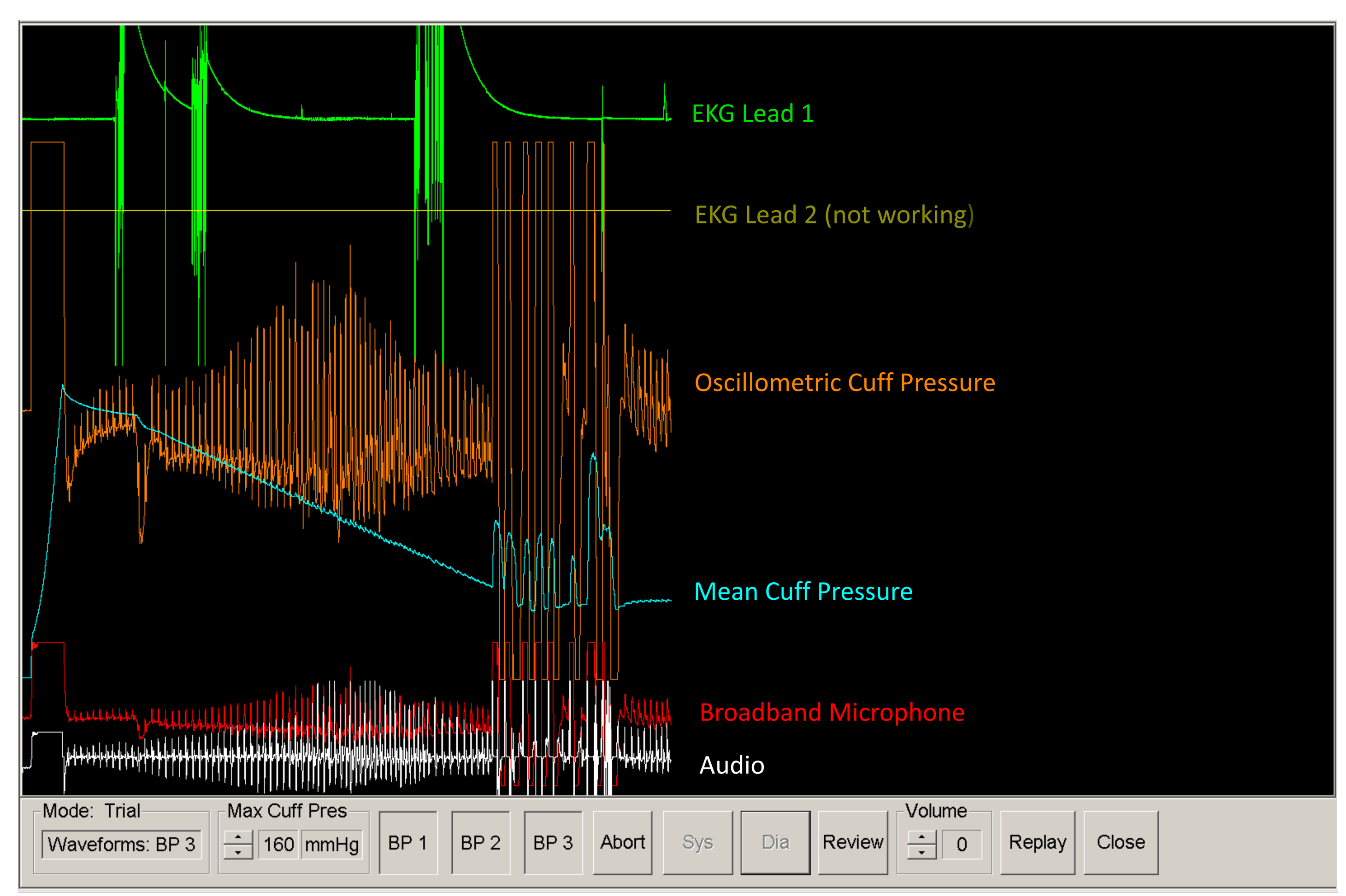

Figure (2). Actual EKG and blood pressure data of a team member acquired from the machine

System Summary:

System 1: Nicolet Cuff Sensor and Nicolet Cuff Inflator
- Pulse pressure waveform, systolic and diastolic pressure, myocardial electrical rhythm

System 2: Nihem and components
- Blood flow, blood pressure, tonometry, blood oxygen levels, myocardial electrical rhythm

System 3: Hokanson Cuff Inflator
- Asculatory systolic and diastolic pressure

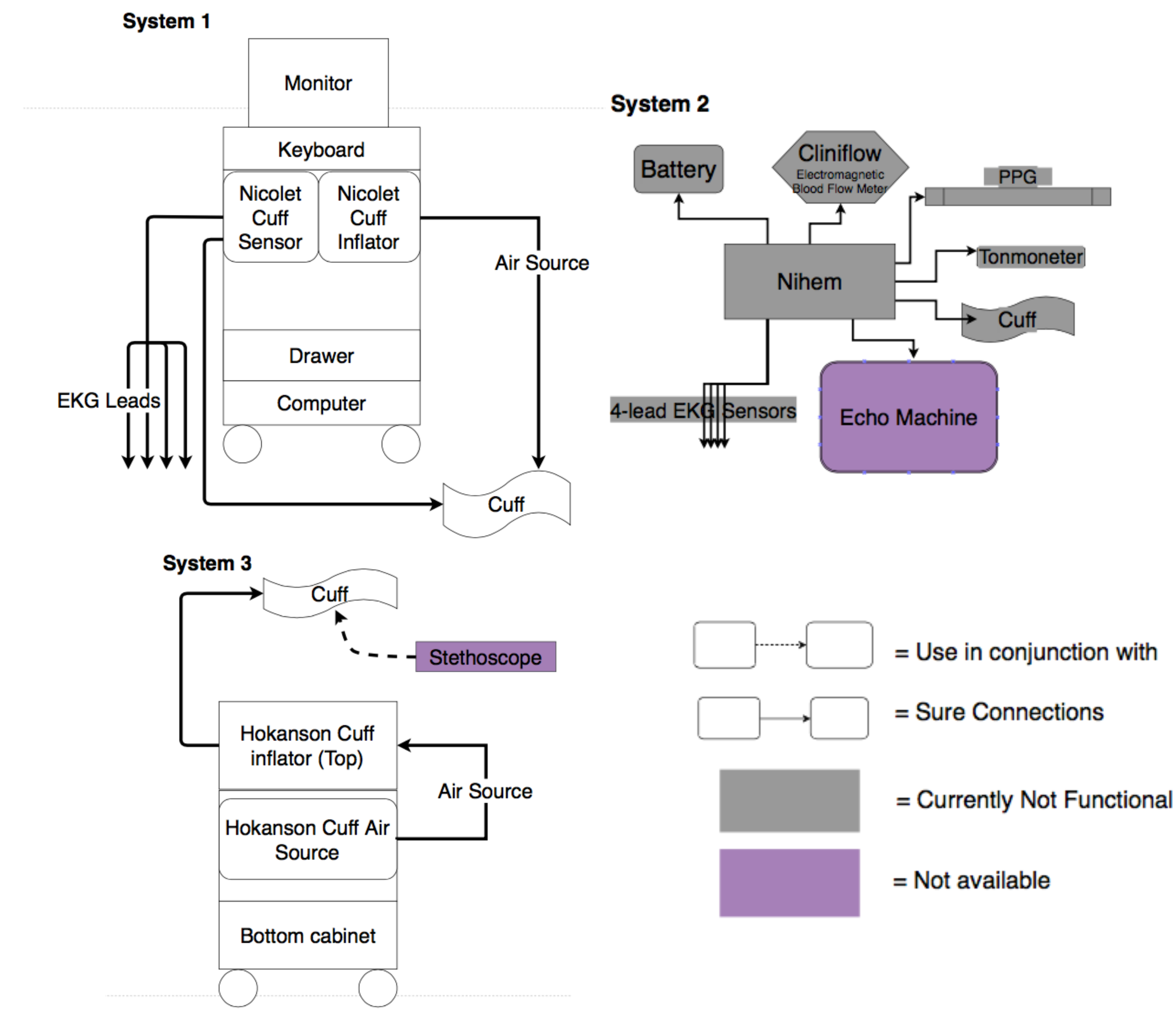

Figure (3). A schematic diagram depicting the integration of instruments that could measure systemic vascular impedance.

CONCLUSION/FUTURE WORK

From the instruments we have working, we can take simultaneous EKG, pulse pressure, and sphygmomanometric data. However, one lead of the EKG does not work. Our client is now aware of the capabilities of the instruments, as well as what instruments are missing.

Future Work

- Complete a manual for the machines
- Acquire a Doppler echocardiogram machine so that data for impedance calculation can be measured and patient testing can be performed
- Further dissection of cardiovascular properties can be solved using the Windkessel model

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