Veterinary Research Scholars Program
University of Missouri

Development of a data-driven algorithm from swine to improve management of human cardiovascular disease

Sierra Crotty, Ghazwan Alwan, T. Dylan Olver, Mouayed Al-Toki, Patrice Delafontaine, Noah Manring, Emily Leary, Craig Emter

Departments of Biomedical Sciences, Mechanical & Aerospace Engineering, Medicine, and Orthopaedic Surgery, University of Missouri, Columbia, MO

ABSTRACT

According to the Centers for Disease Control and Prevention, hypertension is the primary cause or a contributing cause of death in more than 1,000 people each day in the US. Hypertension is a complicated expression of various factors, which include heart function as well as blood flow and pressures. Current methods to diagnose hypertension involve evaluating heartrate and blood pressure readings. As a result, it is often difficult to identify the root cause for hypertension in a specific patient, as these methods do not provide a complete picture of cardiovascular function. We propose that properly assessing cardiovascular health and function requires at least five hemodynamic properties: stroke volume, ejection period, heartrate, systolic pressure, and diastolic pressure. To estimate properties not routinely measured in clinic, we developed a hemodynamic computational method using experimental data from healthy and hypertensive swine, applying the physical principles of mass conservation and the mechanical elasticity of blood vessels. Currently, clinical human data is being compiled into a large, longitudinal data repository, with the goal to refine and validate this computational method for humans. Once validated, this model will be used to describe the complete cardiovascular function state for humans, to enhance clinical monitoring and care, ultimately improving cardiovascular health.

OBJECTIVE

The goal of this research is to test if a newly developed equation designed to measure vascular stiffness is sensitive to changes often caused by human hypertension. The vascular stiffness equation requires 5 hemodynamic inputs: **systolic and diastolic blood pressure, stroke volume, ejection period, and heart rate**. I am organizing human hemodynamic data from control and hypertensive patients to be used to test the sensitivity of the vascular stiffness equation to disease.

HYPOTHESIS

The newly developed equation will be able to detect differences in vascular stiffness between human control and hypertensive patients.

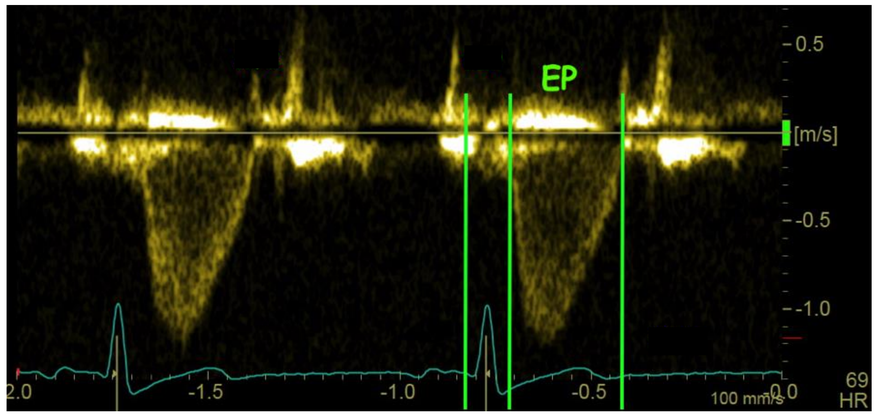
METHODS

Human Data Collection

Heart rate and blood pressure collected from Control and Hypertensive patients during visits where a cardiac echocardiogram was referred will be utilized for hemodynamic inputs. Stroke Volume will be calculated from the echocardiogram were using the following equation:

$$SV = \pi(r^2) \times VTI$$

Ejection Period will be calculated from the echocardiogram using pulse wave Doppler images as illustrated below:



Organization of Human Data

After the data was collected from University of Missouri Hospital billing statements it was compiled into a large, longitudinal data repository. The data was organized by each patients assigned Medical Record Number (MRN). The MRN and date of service was used to identify specific hemodynamic inputs, which are inserted into a excel spreadsheet template for computational assessment of vascular stiffness. A representative Table is presented below demonstrating organization of this patient data in a limited number of subjects.

Patient Number	Heart rate [BPM]	Systolic Pressure [mm-Hg]	Diastolic Pressure [mm-Hg]	Stroke Volume [mL]	Ejection Time [s]
1	86	74	55	TBD	TBD
2	58	110	60	TBD	TBD
3	96	110	58	TBD	TBD
4	80	110	58	TBD	TBD
5	76	134	66	TBD	TBD
6	90	112	67	TBD	TBD
7	84	129	69	TBD	TBD
8	78	97	64	TBD	TBD
9	85	103	62	TBD	TBD
10	120	112	69	TBD	TBD

METHODS

Once the hemodynamic inputs have been extracted from the human patient files, the equation below will be used to calculate vascular stiffness, with group comparisons between Control and Hypertensive Subjects made using an independent samples t-test.

$$Vascular\ stiffness = \left(\frac{Stroke\ volume}{Mean\ pressure}\right) * \frac{1 - \left(\frac{Ejection\ period}{Heartbeat\ period}\right)}{LN\left(\frac{Systolic\ pressure}{Diastolic\ pressure}\right)}$$

Peripheral Vascular Resistance will also be calculated using the equation below:

$$Peripheral\ Resistance = \frac{Heartbeat\ period * Mean\ Pressure}{Stroke\ Volume}$$

RESULTS

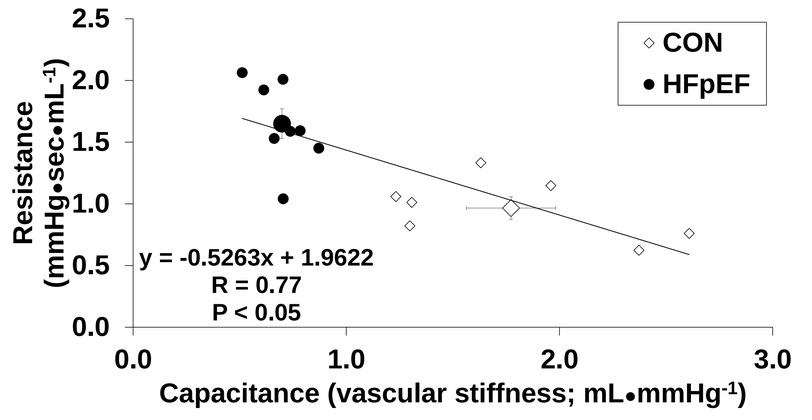


Figure 1. Preliminary validation of new vascular stiffness equation. Cumulative group data, represented by the regression line, show a significant negative correlation between vascular resistance and vascular stiffness i.e. capacitance. Group means reflect a left and upward shift along this relationship in the heart failure with preserved ejection fraction (HFpEF, N=7) patients compared to healthy human controls (CON, N=8), indicating an increase in resistance is associated with an decrease in capacitance.

CONCLUSIONS

Preliminary results indicate this newly developed equation is sensitive to changes in vascular stiffness caused by cardiovascular disease, providing initial evidence that this method of computational modeling may have clinical relevance for diagnostic purposes.

Support

NIH R01 HL112998 PI: Emter, CA
IDEXX-BioResearch.