Validity of impedance cardiography as a measure of pulse wave velocity
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Final Report

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BACKGROUND AND HYPOTHESES

Pulse wave velocity (PWV) measured by ultrasound and doppler is a predictor of clinical cardiovascular events in adulthood (1-2). PWV is conceptualized as a measure of vascular stiffness because it measures the transit time of a pulse wave between two body landmarks divided by distance. Faster transit times are indicative of stiffer vessels. African American adults and adolescents have higher PWV than Caucasians (3-4).

Impedance cardiography is a noninvasive technique for measuring blood flow based upon the change in electrical impedance in a defined region caused by the inflow of blood into that region. The technique is typically applied to the thorax and cardiac output and calculated total peripheral resistance are assessed. Use of impedance measurement from a peripheral limb, however, can assess the arrival time of blood flow after the heart beat. As such the impedance technique has the capacity to measure PWV as well. However, it is unknown the extent to which PWV as estimated by ultrasound and impedance yield similar results. The purpose of this pilot study is to evaluate the association of PWV measured by the two techniques. Should the associations be sufficiently high, impedance cardiography can be used to measure PWV in the context of cardiovascular reactivity studies. Thus, it will not be necessary to conduct studies of reactivity to stress and PWV in two different laboratories, with the greater attendant cost and lower efficiency to both participants and investigators.

METHODS

Participants. Because the study population in which we hope to use impedance cardiography to estimate PWV would include black and white men in their 30's, we recruited 28 black and white community-based men between the ages of 25-35. *Exclusionary criteria* included: current smoking, history and/or treatment for heart disease, hypertension or diabetes, and body mass index > 30.

Protocol. Participants were met at the Ultrasound Research Laboratory. The study protocol was reviewed and informed consent obtained. Impedance bands were applied and participants assumed a supine position for Impedance testing. Immediately following the impedance measure an ultrasound technician applied cuffs and sensors to the participant and the ultrasound measures were obtained. Participants were paid a total of $50 for their time and transportation.

Ultrasound. Three EKG leads were attached. Two blood pressure readings were taken using an automated device (Dinamap, Critikon Company, Tampa, FL) prior to any testing and at the end of the ultrasound measures. The Colin VP-2000 was the automatic device used to measure the carotid and femoral arterial pulse waves (Colin Medical Instruments, San Antonio Texas). This device simultaneously measures electrocardiograms, phonocardiograms, bilateral brachial and ankle blood pressure, and carotid and femoral arterial pulsewaves. The arterial flow waves from the two arterial sites were simultaneously recorded and the output captured and stored in the computer system for subsequent scoring. We performed two data collection runs, each obtaining 30 seconds of simultaneously recorded carotid and femoral flow waveforms. The difference in timing between the two waves is the time component of the velocity equation. Aortic pulse wave velocity was calculated by dividing the distance traveled by the time differential between the two waveforms. Results were averaged from all usable data collection of two runs for each participant.

Impedance Cardiography. A Minnesota Impedance Cardiograph Model 304B was used to obtain basal transthoracic impedance waveforms (Z0) and the first derivative of pulsatile impedance (dZ/dt) waveforms using a tetrapolar lead configuration. We applied disposable aluminum/Mylar band electrodes to the neck and chest with the voltage electrodes placed around the base of the neck and around the thorax at the level of the xiphosternal junction. Current electrodes were placed at least 3 cm distal to each voltage electrode and supplied a 4 mA, 100 kHz signal to the thoracic region. The ECG signal was transduced using two active disposable Ag/AgCl electrodes (Meditrace) placed on each side of the abdomen below the impedance electrode bands, as well a ground electrode beside the navel. A Coulbourn S75-11 amplifier/coupler filters and amplified the ECG signal. Acquisition and storage of ZKG and ECG were accomplished using Mindware, an on-line data acquisition software system for physiological signals. Basal impedance, the first derivative of the pulsatile impedance signal (dZ/dt), and the ECG were sampled at 1000 Hz per channel by a laptop personal computer.

PWV was assessed for the systemic circulation between the aortic flow assessed by the impedance device on the thorax and the calf, i.e., arterial PWV. The measurement from the calf used a second Minnesota Impedance device and four band electrodes with 6 cm separation of recording electrodes centered on the calf and a 2 cm separation of these from the current electrodes. PWV was based on the time between the b-point onset of the impedance signal from the thorax and the b-point onset of the impedance signal from the calf. This time was divided into the distance from above the heart and superficially following the aorta to iliac artery to the midpoint of the impedance measurement site on the calf. The chest measure was followed immediately by the leg measure.

Analyses. Pearson and Spearman correlations were conducted between the two estimates of PWV and paired t-tests were used to calculate mean absolute differences in the estimates. Both estimates were then standardized and the t-test was repeated on standardized values. We anticipated that would be mean absolute differences. We expected a strong positive association between the two measures in the area of .70. Correlations of this magnitude were to be considered to be sufficient to support using impedance cardiography to estimate PWV.

RESULTS

Sample Characteristics

	Age	Race		BMI	SBP	DBP	HR
		Caucasian/ Asian/Indian	African American				
N	28	24	4	28	28	28	28
Mean	28.9			24.4	120.6	69.6	61.1
Median	29			24.1	122.0	69.0	60.5
S.D.	2.9			2.9	8.6	4.8	11.9

Colin PWV and Impedance Measured PWV N = 28

	Colin PWV	Impedance PWV
Mean	1259	708
Median	1275	712

S.D.	117.0	49.2

Analysis on N = 27 (Ss #128 dropped - outlier)
Paired t-test: $t = 29.3$, $P < .001$ Paired t-test on Z scores: $t = .000$, $P = 1.0$
Pearson Correlation: $r = .624$, $P = .001$
Spearman Correlation: $r = .661$, $P < .001$

DISCUSSION
These results suggest that an estimate of PWV can be obtained using two impedance devices that is comparable to that used with substantially more expensive and operator intensive Doppler, ultrasound devices. The absolute values of the PWV differs and the values obtained from the impedance devices are, if anything, more comparable to those derived from invasive studies than the Doppler values. Comparison is hindered by adjustments made using unpublished corrections by the company providing the Doppler device. Doppler assessment requires an operator to appropriate choose heart beats to study and to maintain appropriate probe position. The impedance technique is free from this limitation, but does require the somewhat subjective assessment of the b point on the impedance waveform—as well as some signal averaging over 30 s or 1 minute periods.

Given these considerations, the impedance assessment is not sufficiently close to the Doppler assessment to suggest that one may simply replace the other. In the absence of a 'gold standard', the degree of correlations does raise the possibility that the impedance assessment may be as good an estimate as Doppler estimates. Data are not available though showing that impedance estimates relate to risk or disease endpoints. In short, the results provide a reasonable argument for using the impedance technique, but no guarantee that relationships to external variables will duplicate those using Doppler/ultrasound techniques.

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