Oscillometric Carotid to Femoral Pulse Wave Velocity Estimated With the Vicorder Device

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Carotid to femoral pulse wave velocity (PWV) is associated with an increase in cardiovascular morbidity and all-cause mortality. Noninvasive approach has made this method applicable for the examination of larger populations. This study aimed to obtain reference values of PWV measured with the Vicorder device. PWV was obtained using the oscillometric Vicorder in 318 healthy, normotensive patients (165 women, 28.7±17.6 years, range 6–83 years). A plethysmographic sensor was placed over the right carotid region to pick up the carotid pulse wave and a blood pressure cuff was placed around the upper thigh to trace the femoral pulse wave. Path length was defined as the distance from the suprasternal notch to the top of the thigh cuff. Mean PWV was 6.1±1.4 m/s and significantly increased with age (r=.842; P<.0001). PWV was associated with mean arterial pressure (r=.546; P<.0001) and body mass index (r=.396; P<.0001). In a multiple linear regression model, age, mean arterial pressure, and body height emerged as independent markers for PWV. This study established reference values for carotid to femoral PWV derived by oscillometric measures that can now be used for risk stratification. *J Clin Hypertens (Greenwich)*. 2013; 15:176–179. ©2012 Wiley Periodicals, Inc.

Multiple studies have demonstrated the predictive value of aortic stiffness for cardiovascular events.[1–7] Noninvasive approaches in the measurement of arterial compliance have made this method applicable for the examination of larger populations. The European Society of Cardiology now suggests to measure arterial stiffness for risk stratification.[2] However, arterial stiffness can be assessed by a variety of imaging methods using echocardiography, applanation tonometry, or magnetic resonance imaging. However, depicting the small movements with these methods is challenging.

Carotid to femoral pulse wave velocity (PWV) is the direct measure of aortic stiffness, as stiffer vessels propagate the pulse wave faster. Therefore, carotid to femoral PWV is considered the "gold standard" measurement for arterial stiffness because it is the most simple, noninvasive, robust, and reproducible method.[2]

Most studies for PWV have used applanation tonometry (such as SphygmoCor [AtCor Medical, West Ryde, Australia) to obtain sequential recordings of the waveform with ECG gating to estimate PWV. Recently, a new oscillometric devices (Vicorder [SMT Medical, Würzburg, Germany]) was introduced because it is easy to use and well tolerated by patients.[8] This technique has shown a good intraobserver and interobserver variablility with little operator training, and PWV values are in good agreement with those from SphygmoCor applanation tonometry.[8,9]

Currently, there are only few studies[8–11] using the Vicorder system. Larger cohort studies are lacking. The aim of this study was to assess reference values for the German population using the oscillometric Vicorder device.

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PATIENTS AND METHODS

Study Patients

From June 2011 to January 2012, 297 healthy, normotensive (systolic blood pressure [SBP] ≤140 mm Hg) volunteers were prospectively studied. Patients with hypertensive drugs were excluded from the study and all of the included patients were free from acute or chronic diseases. Study characteristics are displayed in detail in Table I.

Patients were recruited from a pediatric preventive care practice, were students, employees from two companies, accompanying person of patients at our intitutions, or family members or friends of persons already involved into the study.

Blood pressure (BP) was measured automatically with an oscillometric device. Mean arterial pressure (MAP) was calculated from SBP and diastolic BP (DBP) as MAP=DBP+0.33 (SBP–DBP).

The study protocol was approved by the local ethical board (project number 5126/11). All patients gave informed consent.

Measurement of Carotid to Femoral PWV

Measurement was performed in the supine position after 5 minutes of rest using the Vicorder device according to the actual guidelines.[2,12] A 100-mm wide BP cuff was

TABLE I. Epidemiological Data of the 318 Patients According to Age Group

	Study Group (N=318)	≤12 y (n=44)	12–15 y (n=68)	16–19 y (n=31)	20–29 y (n=53)	30–39 y (n=32)	40–49 y (n=36)	50–59 y (n=36)	≥60 y (n=18)
Age, y	28.7±17.6	9.9±1.5	14.1±1.1	17.3±0.9	24.6±3.0	34.6±3.0	44.9±2.8	54.6±2.8	66.8±7.4
Women/men	165/153	16/28	28/40	15/16	40/13	19/13	16/20	24/12	7/11
BMI, kg/m^2	22.5±4.7	18.5±3.6	22.2±5.1	23.5±4.3	21.5±3.0	23.4±3.6	24.4±3.2	25.4±4.4	26.9±3.8
SBP, mm Hg	122.1±9.6	118.0±8.6	120.0±8.5	123.7±8.4	121.4±9.3	123.8±10.4	124.3±7.7	124.9±11.2	127.9±10.5
DBP, mm Hg	65.6±9.3	58.3±6.5	60.1±8.6	64.5±4.9	66.8±8.7	68.3±7.6	73.6±8.2	71.5±7.9	69.6±7.4
MAP, mm Hg	84.4±8.4	78.2±6.2	80.0±7.3	84.2±5.2	84.9±7.9	86.4±7.7	90.5±7.6	89.3±8.1	89.1±6.8
PWV, m/s	6.1±1.4	4.5±0.5	5.1±0.6	5.6±0.6	5.8±0.7	6.5±0.6	7.1±0.9	7.9±1.1	8.2±1.2

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; MAP, mean arterial pressure; PWV, pulse wave velocity; SBP, systolic blood pressure.

FIGURE 1. (**A**) Placement of the carotid sensor to measure carotid pressure wave (provided by SMT Medical). (**B**) Placement of thigh cuff to measure femoral pressure wave (provided by SMT Medical).

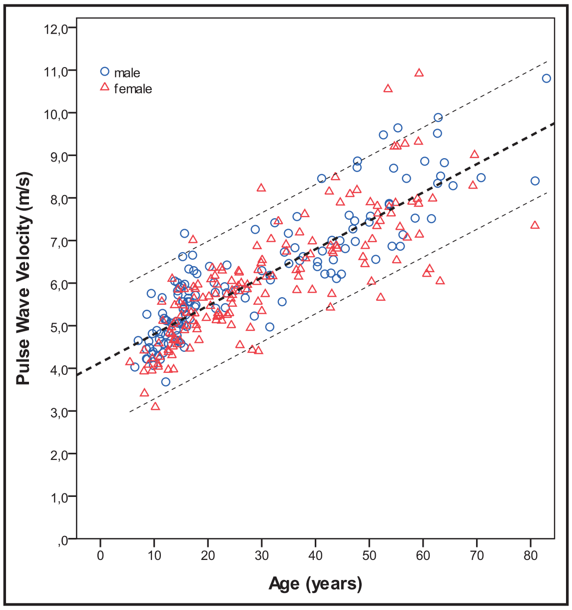

FIGURE 2. Pulse wave velocity in the course of age according to sex in 318 healthy patients.

placed around the right upper thigh to measure the femoral pulse wave and a 30-mm plethysmographic partial inflatable sensor was placed over the carotid region, able to pick up the carotid pulse wave (Figure 1). After preparation, both were inflated to about 60 mm Hg and waveforms were recorded simultaneously over about 10 consecutive heartbeats to estimate transit time. The beginning of systole was identified by an inbuilt foot-to-foot algorithm that was centred around the peak of the second derivative of pressure.[9]

In the present study, path length was defined as recommended by the manufacturer and Hickson and colleagues[9] by a direct measurement between the suprasternal notch to the top of the thigh cuff (for detailed application see http://www.smt-medical.com). This measure has not only been shown to be simple, but that PWV values obtained with this path length are in good agreement with those estimated by the SphygmoCor device.[9]

Carotid to femoral PWV was calculated as:

$$\mathrm{aPWV}\left(\frac{\mathrm{m}}{\mathrm{s}}\right) = \frac{\text{Path length}}{\text{Transit time}} = \frac{\text{Suprasternal notch} - \text{top of thigh cuff}}{\text{Transit time}}$$

Data Analyses

All analyses were performed using PASW 18.0 software (SPSS Inc, Chicago, IL). All descriptive data were expressed as mean values and standard deviation

TABLE II. Univariate Associations Between Pulse Wave Velocity and Demographic Variables

Variable	Pearson's *r*	*P* Value
Age, y	.842	<.0001
Height, cm	.512	<.0001
Weight, kg	.501	<.0001
Body mass index, kg/m^2	.396	<.0001
Men/women	–	.958
SBP, mm Hg	.371	<.0001
DBP, mm Hg	.548	<.0001
MAP, mm Hg	.546	<.0001

Abbreviations: DBP, diastolic blood pressure; MAP, mean arterial pressure; SBP, systolic blood pressure.

TABLE III. Multivariate Regression Analyses on Pulse Wave Velocity Including All Significant Demographic Variables

Variable	Regression Coefficient	Standard Error	Beta	*P* Value	r^2 Change, %
Age, y	0.055	0.003	0.690	<.0001	70.8
MAP, mm Hg	0.032	0.005	0.189	<.0001	3.4
Height, cm	0.016	0.003	0.159	<.0001	2.0

Regression equation: PWV (m/s)=(0.055×age)+(0.032×MAP)+(0.016×height)−0.869
(adjusted r^2=.762, SEE=0.68 P<.0001)

Abbreviations: MAP, mean arterial pressure; PWV, pulse wave velocity; SEE, standard error of the estimates.

(mean±SD). Sex differences in PWV were evaluated using Student's *t*-test.

The Pearson correlation was used to test associations between the PWV and the demographic variables. In a multivariate regression model, the impact of age, age,^{2} body mass index, sex, body height, body mass, as well as systolic, diastolic, and mean arterial pressure on PWV was calculated.

Two-sided *P* values <.05 were considered significant.

RESULTS

Study patients and epidemiologic data of the study group according to the different age groups are displayed in Table I.

As seen in Figure 2, pulse wave was strongly associated with age (*r*=.842, *P*<.0001) and other demographic variables (Table II). There were no differences between men and women (*P*=.958).

In a multivariate regression model, age, mean arterial pressure, and body height emerged as independent factors for PWV (Table III).

DISCUSSION

This study established reference values for carotid to femoral PWV in healthy patients measured by the Vicorder device. Those values can now be used for risk stratification in patient groups who are at risk for long-term cardiovascular disease, as well as in the apparently healthy.

PWV is an important predictive value for cardiovascular risk stratification.[1,2,4–6] Assessing PWV, the SphygmoCor is currently the most evaluated and commonly used device in clinical studies. However, it is known that the tonometric method of the SphygmoCor is highly operator-dependent and requires considerable operator training to guarantee for good interobeserver and intraobserver variability.[8,9,13,14] However, in contemporary studies, it is not unusual to have multiple centers and different study staff conducting PWV measurements.

The Vicorder used in this study is a more recent device, showing convenient handling with good interobserver and intraobserver variability with reasonable amount of training.[8,9] The validity of the PWV measures obtained depends mainly on the correct measurement of the path length.[15] Hickson and colleagues[9] have shown good agreement with the SphygmoCor device when assessing path length between the suprasternal notch (SNN) to the *top* of the thigh cuff. Whereas Kracht and colleagues[8] report good agreement when measuring from the SNN to the *middle* of the thigh cuff and subtracting the distance from the SSN to the carotid cuff from that distance. However, both methods approximately estimate the same distance, because the difference from the top of the thigh cuff to the middle of the thigh cuff is almost the same as the distance from the SSN to the carotid cuff.

In accordance with Hickson and colleagues[9] for routine measurement and scientific research involving different centers and medical staff, we recommend the direct measurement from the SSN to the top of the thigh cuff. In this method only one length has to be obtained, which makes the method less prone to errors.

Considering these methodological issues it is not surprising that the PWV values of the present study show good agreement to PWV values compared with other studies.[5,7,16,17] In concordance with the study of Reusz and colleagues[16] in about 1000 children, age, mean arterial pressure, and height became an independent predictive value for PWV in the pediatric age group. In adults, McEniery and colleagues[17] also estimated a comparable adjusted r^2 of .65 in a multivariate regression analysis for PWV. With almost the same impact as our study, age, mean arterial pressure, and height were an independent predictive value in this model.

Nevertheless, values gathered by different devices should not be used interchangeably. Therefore, this study established reference values for PWV measured with the oscillometric Vicorder device.

Study Limitations

The age group of geriatric patients is underpowered and, therefore, further research in this age group is recommended because Hickson and colleagues[9] found significant higher PWV values measured with the

SphygmoCor in comparison with the Vicorder in this age group.

Moreover, longitudinal studies should be conducted to establish cutoff values for patients at higher risk for cardiovascular events.

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