The evaluation of pulse wave velocity using Arteriograph and Complior apparatus across multiple cohorts of cardiovascular-related diseases

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Arterial stiffness is a well established predictor of cardiovascular morbidity and mortality in several subgroups of patients [1]; hypertensive [2]; diabetics [3]; patients with renal failure [4] or coronary artery disease [5], as well as the general population [6]. Pulse wave velocity (PWV) is an accurate measure of arterial stiffness with an independent prognostic value for cardiovascular risk [7]. Among several techniques, Complior System is considered the best validated method to assess PWV. Compior Analyse uses non-invasive pressure sensors to simultaneously record pulse waves in the carotid and femoral arteries (tonometry). On the other hand, a new technology became recently available, the Tensioclinic Arteriograph. This diagnostic device uses an oscillometric method to detect signals from the upper arm cuff for PWV measurement.

The aim of this study was to compare pulse wave velocity measured by Compior to that measured by Arteriograph. Until now, similar studies have been published including only hypertensive patients [8]. We compared these two methods among patients with several cardiovascular related diseases, such as aortic abdominal aneurysms [9], coronary artery disease, diabetes mellitus, hypertension as well as inflammatory diseases [10].

We studied 416 patients (age 58 ± 14 years) with coronary artery disease (CAD, n = 63), diabetes mellitus (DM, n = 65), hypertension (n = 50), inflammatory diseases (ID, n = 101; 60 patients suffering from rheumatoid arthritis and 41 from psoriasis), abdominal aortic aneurysms (AAA, n = 93) and 44 healthy controls. Patients' age was 58 ± 14 years and 26.6% were women. Each patient underwent weight, height, waist and hip measurements and BMI was estimated. Arterial blood pressure parameters (SBP, DBP, MAP) were also recorded. All patients gave informed consent and institutional ethics committee permission was obtained.

Each patient rested in a supine position for 10 min in a quiet room at 23 °C before the baseline hemodynamic measurements were recorded. Brachial BP and heart rate (HR) were measured in the right arm with an automated digital oscillographic sphygmomanometer (TensioMed, Budapest Hungary, Ltd). Two sequential measurements separated by 2-min interval were obtained and the mean was used for the analysis.

PWVc was measured with an automated system Compior (Alam Medical, Vincennes, France). Two non-invasive pressure sensors were used to record the carotid and femoral waveforms and the distance between the two arterial sites was measured with a tape measure. PWVc was calculated as the distance divided by transit time between waves (m/s).

Arteriograph (TensioMed Budapest Hungary, Ltd) was used in order to obtain the PWVa. An upper arm cuff was applied to the patient and after a first simple BP measurement, the cuff was over-inflated with 35–40 mm Hg beyond the systolic BP. During systole, the blood volume having been ejected into the aorta generates pulse wave (early systolic peak). This pulse wave runs down and reflects from the bifurcation of aorta, creating a second wave (late systolic peak). Both early and late systolic peak were obtained and recorded on the computer as pulse waves. The difference in time between the beginning of the first wave and the beginning of the second (reflected wave) is related to the measured distance from the jugulum to the symphysis, resulting in the PWV in m/s. The software of Arteriograph decomposes the early, late systolic and diastolic waves and also determines the onset and peaks of the waves. For PWV analysis, the onsets of the waves are determined by using first and second derivatives.

Comparisons between subgroups of patients were made by ANOVA. The Bland–Altman methodology was used to assess the agreement between PWVa and PWVc (a mean difference lower than 1.0 is considered not statistically significant). In addition, we performed a ROC curve analysis in order to assess a cut-off value of examined factors predisposing to disagreement between the two methods.

By ANOVA, Arteriograph showed significantly higher levels of PWVc in AAA compared to all other groups [AAA: 11.92 ± 2.67 m/s, CAD: 10.09 ± 2.60 m/s, Hypertension: 10.04 ± 2.33 m/s, ID: 10.18 ± 3.14 m/s and DM: 9.10 ± 2.0 (F = 17.5, p < 0.001)]. PWVc was similar for CAD, Hypertension, ID and DM (p = ns). Lower values of PWVc were found in healthy controls (8.59 ± 1.89 m/s) compared to all patient subgroups (p < 0.05 for all comparisons). The Compior method also showed considerably increased PWVa in AAA (12.08 ± 2.80 m/s, F = 5.2, p = 0.002) compared to the rest of the subgroups and similar values among CAD (10.78 ± 2.7 m/s), Hypertension (10.84 ± 2.18 m/s), ID (10.83 ± 2.54 m/s) and DM (10.4 ± 2.6) (p = ns). Controls (9.41 ± 1.75 m/s) presented with the lowest values of PWVa (p < 0.05 for all comparisons). Both PWVa and PWVc correlated with systolic blood pressure (SBP) [r = 0.248, p = 0.01 for PWVa and r = 0.289, p = 0.01 for PWVc], diastolic blood pressure (DBP) [r = 0.212, p = 0.01 for PWVa and r = 0.230, p = 0.01 for PWVc] and age [r = 0.462, p = 0.01 for PWVa and r = 0.428, p = 0.01 for PWVc]. In all patients, there was a positive association of PWVa with PWVc [r = 0.43, p < 0.001].

The Bland–Altman method (Fig. 1) indicated a mean difference for PWV values between the two methods in all patients: 0.7 m/s (95%CI 0.35–1.05 m/s) with limits of agreement −5.3–6.6 m/s (Fig. 1A), in CAD: 0.8 m/s (95%CI 0.0–1.6 m/s) with limits of agreement −4.8–6.4 m/s (Fig. 1B), in Hypertension: 0.8 m/s (95%CI 0.089–1.511 m/s) with limits of agreement −3.8–5.4 m/s (Fig. 1C), in AAA: 0.2 m/s (95%CI −0.6–0.8 m/s) with limits of agreement −7.0–7.3 m/s (Fig. 1D), in ID: 0.7 m/s (95%CI 0.0–1.4 m/s) with limits of agreement −5.9–7.3 m/s (Fig. 1E), in DM: 0.8 m/s (95%CI 0.25–1.35 m/s) with limits of agreement −1.2–2.8 m/s (Fig. 1F) and in healthy controls: 0.8 m/s (95%CI 0.246–1.353 m/s).

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Average of PWVc and PWVa

**ALL PATIENTS**

- Mean: 0.7
- SD: ±1.96
- Lower Bound: -5.3
- Upper Bound: 6.6

**CAD**

- Mean: 0.8
- SD: ±1.96
- Lower Bound: -4.8
- Upper Bound: 5.4

**HYPERTENSIVES**

- Mean: 0.8
- SD: ±1.96
- Lower Bound: -3.8
- Upper Bound: 5.4

**Abdominal aortic aneurysms**

- Mean: 0.2
- SD: ±1.96
- Lower Bound: -7.0
- Upper Bound: 7.3

**INFLAMMATORY DISEASES**

- Mean: 0.7
- SD: ±1.96
- Lower Bound: -5.9
- Upper Bound: 7.3

**DIABETICS**

- Mean: 0.8
- SD: ±1.96
- Lower Bound: -1.2
- Upper Bound: 2.8

**NORMALS**

- Mean: 0.8
- SD: ±1.96
- Lower Bound: -3.1
- Upper Bound: 4.7

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*Letters to the Editor*
with limits of agreement $-3.1\text{–}4.7$ m/s (Fig. 1G). Therefore, the Bland-Altman analysis demonstrates acceptable limits of agreement between the two methods.

**PWVa but not PWVc correlated with height** (PWVa: $r = -0.16$, $p = 0.001$, PWVc: $r = -0.04$, $p = 0.4$). Using linear regression analysis, height was a statistically significant determinant of the absolute PWV difference (DPWVABS) between the two techniques [unstandardized $B = -0.02$ (95% CI $-0.033$–$-0.004$, $p = 0.24$) and standardized $B = -0.12$] among BMI, weight, age, sex, smoking, heart rate and blood pressure parameters. Moreover, we performed a ROC curve analysis in order to assess a cut-off value of height predisposing to a difference greater than $3$ m/s (upper quartile of the absolute difference) between PWVa and PWVc (area under the curve $0.65$ with 95%CI $53$–$73$, cut-off value $<167$ cm with 60% specificity and 70% sensitivity).

In the present study we have shown that both methods were able to detect increased PWV in patients with cardiovascular related diseases against healthy individuals. Moreover, patients with aortic abdominal aneurysms had higher PWVc and PWVa compared to patients suffering from hypertension, diabetes mellitus or inflammatory diseases who showed similar PWV values. Additionally for the first time, we have shown that PWV measurement obtained with the Arteriograph was similar with that of Complior in a wider range of patients with cardiovascular related-diseases other than hypertension. Our study extends similar observations reported in hypertensives [11] to novel cohorts of patients with cardiovascular related-diseases.

Regarding to the overall study cohort, a mean difference of $0.7$ m/s (95%CI $0.35$–$1.05$ m/s) between PWVc and PWVa was estimated when measuring PWV among patients with various cardiovascular related-diseases. Low height predisposes to greater difference in PWV values estimated by the two techniques, so accurate distance measurement is necessary among such patients.

The authors of this manuscript have certified that they comply with the Principles of Ethical Publishing in the International Journal of Cardiology.

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