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COMMENTARY

Measuring regional arterial stiffness in patients with peripheral artery disease: innovative technology

Valérie Tikhonoff and Edoardo Casiglia

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The routine measurement of pulse wave velocity (PWV) made the non-invasive evaluation of aortic stiffness a reality, both in clinical practice and in research settings. These routine measurements also revealed that this stiffness accurately reflects aortic calcium content.[1]

Theoretically, the measurement of PWV is easy; it is sufficient to detect the pulse wave in two body districts and then calculate the velocity using the transit time. Many methods are currently available to take these measurements (Table 1). Those methods based on applanation tonometry (that is, methods using a micromanometer-tipped probe applanating the artery; this produces a signal approximating the instantaneous arterial pressure[2]) are traditionally considered to be the gold standard.[3] Applanation tonometry, in particular, the use of the SphygmoCor system (AtCor Medical, Sydney, NSW, Australia) applied to large-scale studies showed that regional arterial stiffness expressed, as the carotid–femoral PWV is correlated with cardiovascular outcomes and with cardiovascular risk in general (Figure 1).

Apart from the training required and the fact that the procedure is largely dependent on the operator, the main problem with applanation tonometry is that waves obtained at arterial and femoral sites are recorded sequentially, not simultaneously, and must be related to each other by means of electrocardiographic tracings (the so-called foot-to-foot method). Relating the waves requires that no physiological variations occur between the two measurements. Given that the carotid and femoral waveforms are recorded sequentially, any variability in the heart rate or blood pressure may confound the readings. Consequently, both expert consensus documents[4] and all scientific articles on PWV enumerate a list of recommendations, which are time-consuming and partially out of the researcher's control, to be strictly observed during measurement.

The piezoelectronic system (Complior; Colson, Les Lilas, France) is electrocardiogram-independent and allows the simultaneous recording of carotid and femoral waves. Therefore, this system is potentially less error prone. Many large-scale studies have been performed with the Complior device, demonstrating the predictive value of PWV in an epidemiological setting.[4] Ultrasound methods also allow the simultaneous measurement of pulse waves at the carotid and femoral sites,[4] but these methods are demanding, strongly operator-dependent and not easy to use in large-scale epidemiological studies, for instance, in population-based studies.

More recently, thanks to technological progress, the market started to prioritize ease of use in addition to reliability. As a consequence, user-friendly and patient-friendly devices have appeared. It is only natural that those devices would take measurements at two sites simultaneously.

The oscillometric method based on two cuffs, one placed on the neck and the other on the thigh, appears to be sufficiently easy to perform to suggest its use in large-scale studies. Its main advantage is that it does not require a long training period and has little operator dependence. Furthermore, the measurement can be performed faster, and the simultaneous carotid and femoral recordings make the observations more reliable and less dependent on the physiological stability of the subject. Two oscillometric devices, the Vicorder[5–7] (Skidmore Medical, Bristol, UK) and the Arteriograph[8] (TensioMed, Budapest, Hungary), have been validated in different samples, demonstrating a good intra- and inter-observer repeatability and good agreement with applanation tonometry. One study comparing the Vicorder and the SphygmoCor in a subset of patients with peripheral artery disease, by Shahin *et al.*,[9] appears in this issue of *Hypertension Research*.

To be more precise, the values obtained with the Vicorder and those obtained with the SphygmoCor are not exactly the same, the former being generally lower than the latter. This difference seems to be due predominantly to a difference in the measured transit time, a difference that is attributable to the presence of a thigh cuff, making the femoral recording point distal to the inguinal canal, which is the reference point for the SphygmoCor.[5,7] The effects of this difference can be minimized by adjusting for the additional femoral artery segment when applying the multivariate algorithms.[7]

Other authors attribute the imperfect agreement between the Vicorder and the SphygmoCor to more tangible factors. First, the SphygmoCor uses the systolic upstroke to detect the pressure wave, whereas oscillometric devices detect the time point of maximal pressure, a point that can differ from site to site.[6] Theoretically, the SphygmoCor is therefore independent of pressure variations during the hemodynamic cycle and might be expected to show better reproducibility.[6] Nevertheless, the SphygmoCor algorithms also take into account the humeral blood pressure.

V Tikhonoff and Professor E Casiglia are at the Department of Medicine, University of Padova, Padova, Italy.
E-mail: edoardo.casiglia@unipd.it

Table 1 Current methods and devices used for determining aortic stiffness

System	*Device*	*Methods of pulse wave detection*	*Advantages and disadvantages*	*Carotid-femoral pulse wave detection*
Plethysmography	Vicorder, Arteriograph	Oscillometric	Humeral blood pressure also measured; less training required; less operator-dependent; not necessary to undress and expose inguinal region; neck discomfort.	Simultaneous, ECG-independent
Mechano-transduction	Complior	Piezoelectronic	Brief procedure, shorter training.	
Applanation tonometry	SphygmoCor, PulsePen	Tonometric	Wave reflections and derived aortic BP also detected; pulse wave analysis allowed; time consuming; training needed; operator-dependent.	Sequential, ECG-dependent
Ultrasounds	Philips etc.	Tissue Doppler	Strongly operator-dependent; long training needed; time-consuming; possibility to study blood flow and arterial wall	
Echotracking	WallTrack, Artlab, NIUS02	Wall motion		

Abbreviations: BP, blood pressure; ECG, electrocardiogram.

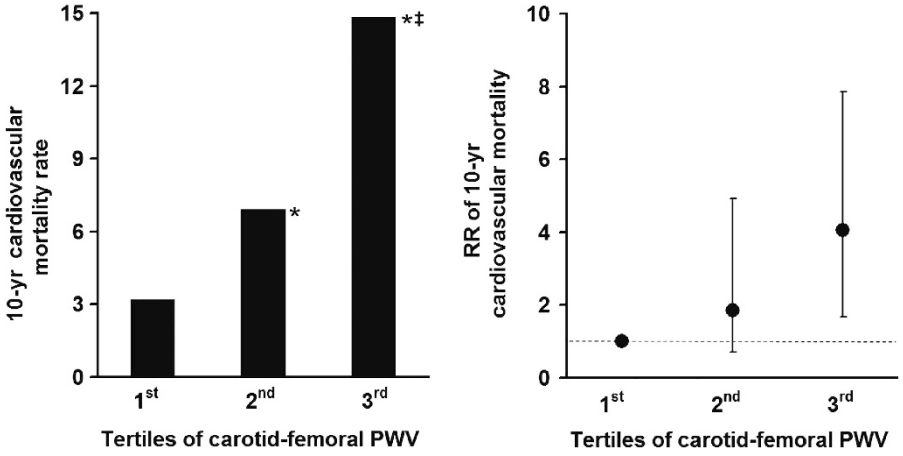

Figure 1 Ten-year cardiovascular mortality rate (left panel) and relative risk (RR) of cardiovascular mortality (right panel) by tertiles of the carotid–femoral pulse-wave velocity in 565 subjects from the general population aged 18 to 95 years (mean 51 ± 16). Unpublished data from the LEOGRA (Last Evidences of Genetic Risk factors in the Aged) study. *$P<0.01$ versus previous tertile; ‡$P<0.01$ versus first tertile.

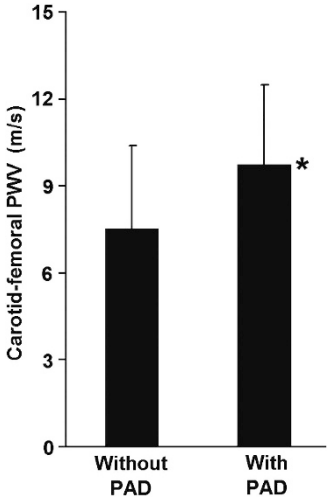

Figure 2 Carotid–femoral pulse wave velocity (PWV) according to the presence of peripheral artery disease (PAD) in 565 subjects from the general population aged 18 to 95 years (mean 51 ± 16). Unpublished data from the LEOGRA (Last Evidences of Genetic Risk factors in the Aged) study. *$P<0.01$ versus subjects without PAD.

Furthermore, to be pedantic, these authors found higher values for PWV with the Vicorder than with the SphygmoCor,[6] whereas all the other researchers tendentially found lower values with the former than with the latter.[7,9] This discrepancy leaves the question open.[10]

The study by Shahin *et al.*[9] was performed with patients with peripheral artery disease, a condition that is of increasing interest because of its high prevalence in the general population, but is generally neglected in angiological studies. This disease is often considered an exclusion criterion. The presence of a stenosis could, in fact, be deceptive. The question as to whether PWV can be reliably measured in such subjects using a simple non-invasive device despite atherosclerotic plaques in the lower limbs—or whether, on the contrary, these measurements are hampered by technical limits—has been unanswered until now. In our experience, carotid–femoral PWV is 30% higher in subjects with peripheral artery disease (Figure 2), a difference that could be due either to a higher systemic wall stiffness or to misleading plaque-dependent local turbulence under the detector. Shahin *et al.*[9] demonstrated that, although the Vicorder offers results comparable to those of the gold standard in terms of PWV, its use in arteriopathic subjects was easier and its results less dependent on local stenosis, thus opening the road to the epidemiological evaluation of patients with peripheral artery disease. Other studies addressing this topic in larger groups of subjects are necessary.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

1 Kullo IJ, Bielak LF, Turner ST, Sheedy PF 2nd, Peyser PA. Aortic pulse wave velocity is associated with the presence and quantity of coronary artery calcium: a community-based study. *Hypertension* 2006; **47**: 174–179.
2 Haluska BA, Jeffriess L, Mottram PM, Carlier SG, Marwick TH. A new technique for assessing arterial pressure wave forms and central pressure with tissue Doppler. *Cardiovasc Ultrasound* 2007; **5**: 6.
3 Kis E, Cseprekál O, Kerti A, Salvi P, Benetos A, Tisler A, Szabó A, Tulassay T, Reusz GS. Measurement of pulse wave velocity in children and young adults: a comparative study using three different devices. *Hypertens Res* 2011; **34**: 1197–1202.
4 Laurent S, Cockcroft J, Van Bortel L, Boutouyrie P, Giannattasio C, Hayoz D, Pannier B, Vlachopoulos C, Wilkinson I, Struijker-Boudier H. European Network for Non-invasive Investigation of Large Arteries. Expert consensus document on arterial stiffness: methodological issues and clinical applications. *Eur Heart J* 2006; **27**: 2588–2605.
5 Kracht D, Shroff R, Baig S, Doyon A, Jacobi C, Zeller R, Querfeld U, Schaefer F, Wühl E, Schmidt BM; Melk A4C Study Consortium. Validating a new oscillometric device for aortic pulse wave velocity measurements in children and adolescents. *Am J Hypertens* 2011; **24**: 1294–1299.
6 Van Leeuwen-Segarceanu EM, Tromp WF, Bos WJ, Vogels OJ, Groothoff JW, van der Lee JH. Comparison of two instruments measuring carotid-femoral pulse wave velocity: Vicorder versus SphygmoCor. *J Hypertens* 2010; **28**: 1687–1691.
7 Hickson SS, Butlin M, Broad J, Avolio AP, Wilkinson IB, McEniery CM. Validity and repeatability of the Vicorder apparatus: a comparison with the SphygmoCor device. *Hypertens Res* 2009; **32**: 1079–1085.
8 Baulmann J, Schillings U, Rickert S, Uen S, Düsing R, Illyes M, Cziraki A, Nickering G, Mengden T. A new oscillometric method for assessment of arterial stiffness: comparison with tonometric and piezo-electronic methods. *J Hypertens* 2008; **26**: 523–528.
9 Shahin Y, Barakat H, Barnes R, Chetter I. The Vicorder device compared with SphygmoCor in the assessment of carotid–femoral pulse wave velocity in patients with peripheral arterial disease. *Hypertens Res* 2013; **36**: 208–212.
10 Palatini P, Casiglia E, Gasowski J, Głuszek J, Jankowski P, Narkiewicz K, Saladini F, Stolarz-Skrzypek K, Tikhonoff V, Van Bortel L, Wojciechowska W, Kawecka-Jaszcz K. Arterial stiffness, central hemodynamics, and cardiovascular risk in hypertension. *Vasc Health Risk Manag* 2011; **7**: 725–739.