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COMMENTARY

New approach to arterial stiffness: BP-independent local carotid stiffness

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Increased arterial stiffness is known to be an independent risk factor for future cardiovascular events.[1–3] Increased arterial stiffness is thought to produce several harmful effects on the cardiovascular system, such as an increased cardiac afterload, peripheral microvascular damage, impairment of the coronary blood supply and arteriosclerotic ischemic stroke.[4,5] Conventionally, pulse wave velocity (PWV) is used as a marker to reflect arterial stiffness. PWV reflects segmental arterial elasticity.[6] However, the PWV reflects the segmental arterial stiffness, and not the local arterial stiffness, in the systemic arterial tree, and the PWV is incapable of discriminating between these segments.

Contraction of the left ventricle generates a pulse wave that is propagated throughout the arterial tree. The Moens–Korteweg equation states that the PWV is proportional to the square root of the incremental elastic modulus of the vessel wall, given a constant ratio of the wall thickness to the vessel radius and blood density. Therefore, increases in the arterial rigidity and arterial wall thickness act to increase the PWV.[7] The PWV can be measured for any arterial segment between two pulse wave palpable regions.

Arterial stiffness is determined by functional factors, such as blood pressure, heart rate and/or vascular tone, as well as structural factors, such as vascular hypertrophy and the proliferation of vascular smooth muscle cells and/or connective tissues. High blood pressure (BP) is associated with increased functional arterial stiffness via an increase in arterial wall tension.[8] Therefore, the use of PWV to assess the intrinsic arterial stiffness must take the BP into consideration. Because of this reason, until now, a blood pressure-independent measurement of arterial stiffness has been developed. The stiffness index β, which reflects the local and not the segmental arterial stiffness in the systemic arterial tree, was calculated using the exponential relationship between arterial pressure and diameter reported by Hayashi *et al.*[9] Therefore, the stiffness index β is theoretically independent of blood pressure. The cardio-ankle vascular index (CAVI) is an index of the overall stiffness of the artery from the origin of the aorta to the ankle. CAVI is closely related to the stiffness index β and is also theoretically independent of blood pressure.[10,11] Thus, these markers require less consideration of the BP. Recently, Steppan, *et al.*[12] proposed the novel arterial stiffness index (ASI), which was defined as the slope of the midline between the data of a parametric plot of PWV *vs.* pulse pressure as diastolic BP is increased. ASI is robust over a range of BPs and allows one to distinguish between compliant and stiff vasculature in rats.

The table summarizes the characteristics of markers related to arterial stiffness. Several meta-analyses have demonstrated that the PWV is an independent risk factor for future cardiovascular events. Recently, van Sloten *et al.*[13] reported that carotid stiffness can predict a future stroke independently of the PWV. This finding suggests that the assessment of local arterial stiffness in a target organ may provide additional information for predicting potential damage to that target organ (Table 1).

Bruno *et al.*[14] investigated the possibility that the association between increased aortic and carotid stiffness and organ damage might differ in multiple organs (kidney, blood vessels and heart) among hypertensive subjects. Interestingly, 'segmental' arterial stiffness assessed using carotid–femoral pulse wave velocity (cfPWV) was associated with renal damage and 'local' arterial stiffness assessed using carotid pulse wave velocity (cPWV) was associated with cardiac damage. A concomitant increases in both cfPWV and cPWV did not have an additive effect on organ damage. This finding helps to differentiate the roles of different arterial segments, either 'segmental' or 'local,' in vascular and cardiac dysfunction.

However, since cPWV is calculated using the Bramwell–Hill relationship,[15] it depends on the BP. In addition, performing ultrasonic wall-tracking and tonometry measurements require special training and experience. The study by Spronk *et al.*[16] in this issue of *Hypertension Research* demonstrated that by using distensibility measurements at the carotid level and a mechanistic approach, the effect of the blood pressure on the cPWV could be assessed in individual patients, rather than using a group adjustment for BP. This approach is based on a single-exponential relationship that is fitted to arterial pressure area measurements and allows the estimation of any changes in stiffness caused by changes in wall material that are not caused by the BP. This mechanistic approach using a patient-specific BP correction technique is both novel and interesting. This 'BP-independent local PWV' measure may be a marker of pure vascular dysfunction. On the other hand, 'BP-dependent PWV,' such as cfPWV and brachial-ankle pulse wave velocity (baPWV), is a marker of both hemodynamics and vascular dysfunction. The differences between these two types of methods must be understood and the applications of each method in clinical settings should be considered. Further

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Table 1 Characteristics of various arterial stiffness measurements

	cfPWV	*baPWV*	*CAVI*	*Stiffness index* β	*Local carotid PWV*	*Local carotid PWV with mechanistic approach*
Area	Segmental (systemic arterial tree)	Segmental (systemic arterial tree)	Segmental (systemic arterial tree)	Local	Local	Local
Less BP dependent	No	No	Yes	Yes	No	Yes
Easy to measure	Medium	Yes	Yes	No	No	No

Abbreviations: baPWV, brachial-ankle pulse wave velocity; BP, blood pressure; CAVI, cardio-ankle vascular index; cfPWV, carotid–femoral pulse wave velocity.

studies are needed to compare this 'BP-independent local PWV' measure with the 'BP-independent' stiffness index β and to assess its value as a predictor of cardiovascular disease in a prospective study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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