European Journal of Preventive Cardiology
ESC European Society of Cardiology

Commentary

European Journal of Preventive Cardiology
2018, Vol. 25(14) 1496–1497

DOI: 10.1177/2047487318794263
journals.sagepub.com/home/ejpc
SAGE

Total arterial compliance: An underestimated biomarker

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One of the most important functional and biomechanical properties of the arteries is their ability to distend due to an increase in the pressure of flowing blood on the arterial wall. This is not a simple phenomenon, however, mainly due to the composite structure of the arterial wall. This complex arterial wall behaviour can most accurately be characterized as viscoelasticity because the deformation of the vascular wall depends on the rate of application of the force (pressure) in addition to its magnitude and exhibits a time-dependent strain.[1] In clinical practice, more simple terms, definitions, mathematical formulas and techniques have been proposed to characterize different facets of arterial mechanical properties, such as distensibility, stiffness, elasticity, compliance and rigidity.[2]

The arterial compliance of a single arterial site, an arterial segment or an arterial network represents a major biomechanical factor with established pathophysiological importance. Vascular ageing and its corresponding phenotypes (the gold standard is arterial stiffness) is an early phenomenon, often preceding the clinical manifestation of disease or target organ damage. In this context, the assessment of arterial compliance offers substantial information with proved predictive and preventive value in cardiovascular risk management.[3,4]

Physiologically, the left ventricle ejects, at a given driving pressure, a specific blood volume (stroke volume) into a compliant vascular network. Given that the arterial walls are sufficiently compliant: (a) the pulse pressure for the specific blood volume remains low; (b) a lower stress is applied on the arterial walls; (c) the oxygen consumed by the myocardium is lower, meaning that left ventricular performance is maintained at lower energetic cost; (d) a percentage of the ejected blood volume during cardiac systole is stored by the arterial system (due to the distensibility of the arterial walls), thus maintaining the blood flow during cardiac diastole; (e) coronary flow (perfusion) is favoured during the diastolic phase of the cardiac cycle; and (f) the transmission of the arterial pulse (i.e. pressure) waves along the arterial tree is at a low speed (most commonly termed the pulse wave velocity; PWV), resulting in a slower return of reflected waves at the central aorta (at late systolic phase) and, consequently, to a smaller effect on the left ventricular afterload due to weaker wave reflections.[5] Logically, the inverse of these events occurs when the arterial wall becomes stiff – namely, the arterial compliance is decreased, a phenomenon directly linked with ageing as well as other lifestyle (i.e. diet, fitness),[6–8] environmental, genetic and pathological factors.

Technically, it is currently impossible to measure directly the total compliance (C_{total}) of the entire arterial system or the systemic arterial tree in vivo. Only indirect methods and techniques have been proposed for the estimation or prediction of C_{total} using in vivo recordings of haemodynamic parameters, in addition to mathematical formulas and models, such as the pulse pressure method,[9] the area and decay time method,[10] the stroke volume to aortic pulse pressure ratio[11] and Windkessel models.[10] The major limitation of these techniques is their practical complexity, which derives from the necessity to simultaneously measure/record aortic blood pressure and flow waves.

An alternative, simple and easily applicable method for the estimation of C_{total} has been proposed based on the use of the gold standard measure of arterial stiffness per se – namely, the carotid-to-femoral PWV.[12] Using a one-dimensional mathematical model of the arterial tree, a simplified formula based on the Bramwell–Hill equation was described and validated in silico.[12] Despite the approximations and assumptions needed to derive a simple formula expressing C_{total}, it was

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found that this estimate of C_{total} could predict mortality in an elderly population, whereas the PWV did not.[13] C_{total} was also found to be better related to the left ventricular mass than the aortic PWV.[14]

Advances in sensor technology and computer science will further simplify and optimize the available techniques for the accurate estimation of total arterial compliance, adding a promising tool for better cardiovascular risk assessment, prediction and prevention in parallel to classic haemodynamic assessment. In the era of precision medicine, the assessment and management of blood pressure related cardiovascular risk could be optimized if cost-effective, easily measured and reproducible vascular biomarkers are incorporated into diagnostic algorithms and predictive models, or even become additional therapeutic targets in parallel to the existing targets.

Author contributions

TGP and MV contributed to the conception of the work. TGP and MV drafted the manuscript. DT critically revised the manuscript. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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