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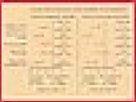

Second Edition

Chapter 15

Clinical Applications of Arterial Stiffness in Hypertension

Roland Asmar

Epidemiologic studies have shown that cardiovascular disease related to arterial lesions is the leading cause of morbidity and mortality in the Western countries. Arterial abnormalities have been observed at early stages of cardiovascular diseases, particularly in the presence of risk factors, principally hypertension. The arteries are the site of hypertension-induced organ damage that compromises the function of various organs: the kidney (nephrosclerosis), the brain (stroke), the heart (angina-myocardial infarction), and the aorta (aneurysm). Therapeutic trials have shown that arterial lesions appear in some treated hypertensive patients and that the effect of cardiovascular drugs on the arterial wall may differ among compounds. Accordingly, assessment of arterial wall properties has been embraced by the world of hypertension research as an important activity.

During the last decade we have had an extraordinary advance in the methodologic aspects of noninvasive determination of the mechanical properties of the large arteries, principally arterial stiffness, related to the development of new ultrasound techniques and computer processing. A consequence of this remarkable development is the availability of devices that allow not only the evaluation of arterial stiffness but also its estimation at different sites in the arterial tree and assessment of other hemodynamic parameters of the arterial wall such as pulse pressure, pulse contour analysis, arterial diameter, wall thickness, and distal compliance.

The growing interest in arterial stiffness is reflected by an increasing number of publications, by the number of ongoing studies, and by development of drugs that act specifically on the arterial wall. Despite this increasing interest, there remains a profusion of methodology and terminology in the literature that can cause confusion and make it impossible to compare results between studies and between research groups.[1] This review is focused on the clinical applications of arterial stiffness measurements in patients at high cardiovascular risk, principally those with hypertension.

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In clinical research, *arterial stiffness* is the most simple and common term used to describe the mechanical properties of the large arteries.[2-5] The terms *compliance* and *distensibility* are also widely used, although they imply a more quantitative approach. Some fundamental hemodynamic principles should be recalled to understand the different definitions used to describe arterial stiffness in clinical practice, to note their limitations, and to provide some normal values.

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The most widely accepted model of the arterial system is a simple tube with one end representing the peripheral resistance and the other receiving blood from the heart.[5] A wave generated by cardiac contraction travels along the tube toward the periphery and is reflected back from the periphery. Thus the pressure wave at any point along the tube is the resultant of both the incident and the reflected waves (Figure 15–1). The incident wave is influenced by the left ventricular ejection and the arterial stiffness (pulse wave velocity [PWV]); the reflected wave is related to arterial stiffness and the characteristics of the reflected waves. *Local* arterial stiffness refers to measurements performed locally on a cross-sectional area of straight artery. *Regional* (segmental) stiffness refers to measurements performed over a segment of the arterial tree or on a regional arterial circulation. *Systemic* (global) stiffness refers to the compliance of the whole arterial tree. In clinic, arterial stiffness should be investigated either locally to explore vascular damage or in the regional and/or systemic circulations to explore the interactions between the heart and vessels (Table 15–1).

In most cases, measurements are done locally on superficial and straight arteries. The vessel is considered a portion of a cylindrical tube in which the relationship between blood pressure and volume (or lumen diameter or cross-sectional area) is established, and its slope represents an index of stiffness. From these measurements, stiffness changes were described as universally accepted indices called *distensibility*, *compliance*, *elastic modulus* (Peterson), and *incremental elastic modulus* (Young) (see Table 15–1). Because of the curvilinearity of the pressure-diameter relationship, all of these parameters are highly pressure dependent. Thus, to evaluate the degree of stiffness of the arterial wall material, blood pressure should be considered and isobaric measurements should be performed according to the local arterial pressure.

Local determinations of arterial stiffness are performed by using ultrasound techniques in which several aspects have to be considered. First, the stiffness indices represent dynamic and not static measurements.[5,6] Therefore, changes in pressure (pulse pressure) and changes in volume (or lumen diameter or cross-sectional area) are measured locally at the same arterial location (e.g., the carotid). Second, because the measurements are exclusively cross-sectional, it is assumed that the length of the artery remains constant over time. Third, because the arterial tree is heterogeneous, it is important to investigate both proximal (elastic) and distal arteries (muscular).[7]

The most common measure of regional (segmental) arterial stiffness is PWV.[8] The principle of PWV is based on the fact that left ventricular ejection volume of blood into the