A Comparison of Arterial Stiffness, Pulse Wave Velocity, and Compliance

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The indices covered in this study measure arterial elastic modulus. However, since each possesses points of physical difference, they should neither be conflated nor confused. It is essential that we determine in what way they are similar and different.

Arterial Stiffness Index (ASI)

The ASI is an index that indicates arterial stiffness from the relationship between pressure and volume in the artery at the point of measurement. Arterial stiffness varies according to the arterial pressure (or, the pressure between the arterial and external pressure). When arterial pressure is low, or when the difference between arterial and external pressure is small, the artery is soft and as arterial pressure rises, so too does arterial stiffness. Since ASI provides the range of pressure in the region where arterial stiffness is smallest, when the ASI is small, the artery is soft, and as ASI increases, it indicates increasing arterial stiffness.

Pulse Wave Velocity (PWV)

The PWV indicates the velocity of pressure waves along the artery. This relationship may be explained physically in the following equation.

$PWV = \sqrt{E \times \frac{h}{\rho} \times D}$ Where, E represents arterial elastic modulus (Young's Modulus), and when this value is large, the arterial hardness is great. The thickness of the arterial wall is h and D is the arterial diameter. Blood density (ρ) may be thought of as a permanent property within the circulatory system. If the artery is thought of as consistent throughout, h/D becomes a constant. For instance, differences in arterial thickness, which lead to differences in physical constitution, are not reflected in the PWV.

Thus, in the case of arterial stiffness, h increases simultaneously with E, and PWV increases as a result. However, since arterial Young's Modulus E increases with arterial pressure, a portion of PWV also changes according to pressure. With regard to changes in multiple factors, PWV as a square root equation reflects only a small portion of these changes.

Compliance

Compliance (C) is the ratio between arterial volume change (ΔV) and pressure change (ΔP).

The Compliance value increases in proportion to arterial elasticity. Thus, by applying the arterial-pressure volume relationship as described in the ASI section above, we can derive arterial static compliance. Arterial compliance is large when arterial pressure is low and small under conditions of higher arterial pressure. As compliance is dependent on arterial pressure, when compliance is measured to express arterial stiffness, the level of blood pressure under which compliance was obtained is important. By simply comparing the size of compliance, one cannot determine which artery is undergoing stiffening.

Furthermore, the size of the artery under measurement also influences the value of compliance. In other words, since compliance indicates arterial volume change against the pressure change, a large artery which shows very large arterial volume changes against normal arterial pressure change, will yield a higher compliance value than will a smaller artery. This becomes a problem when comparing the value of compliance in different sizes of arteries in different sizes of arms.

Arterial pulse pressure is an index that is related to the arterial compliance of systemic arteries in the whole body. If in one heart beat the ΔV of blood delivered by the arteries is constant, the change in arterial pressure (ΔP) appears as pulse pressure, $C = \frac{\Delta V}{\Delta P}$ and is inversely proportional to compliance. For this reason, it may be assumed that when ΔP is large (the artery is stiff), the systemic compliance is small. While compliance at this time is dependent on the blood pressure (in particular mean blood pressure) it also can be expressed as an index that relates to mean arterial pressure during measurement.

ASI reflects arterial stiffening even when arterial transmural pressure (difference between internal and external pressure of the artery) is almost 0. In this condition, the elastic modulus of the artery very much depends on the elastic properties of the tunica media region. Since the tissue of this area is strongly related to arteriosclerotic progression and/or arterial smooth muscle stress, ASI's range of variation is great in comparison with the other indices. For instance, ASI indicates change within a 15-fold range of 20-300 and above. The other indices are highly dependent on blood pressure during measurement and reflect the arterial outer membrane under normal pressure. The arterial outer membrane consists mainly of collagen fiber and naturally possesses stiff properties. For this reason, these other indices are far less efficient in comparison with the ASI in detecting changes in arterial stiffness progression and arterial smooth muscle stress, and, possess at best no more than a two-fold range of variation.