

SphygmoCor and Cardiovascular Risk

Large artery stiffness and accelerated wave reflections that lead to increased pressures at the heart have been associated with many of the common cardiovascular risk factors, such as age, high blood pressure, smoking, cholesterol levels and obesity, but importantly have also been shown to be independent predictors of cardiovascular morbidity and mortality in several population groups.

Central blood pressure and measures of arterial stiffness have been demonstrated to be important parameters in assessing cardiovascular risk. Central systolic pressure has been shown to be an independent predictor of incident cardiovascular disease, independent of brachial systolic blood pressure¹. The aortic augmentation index (Alx) and aortic pulse wave velocity (PWV), measures of systemic and aortic stiffness, have been associated with ageing and in patients with hypertension, diabetes, hypercholesterolaemia and renal disease², all of which have a high incidence of cardiovascular risk. Both of these parameters have been shown to be strong independent predictors of all-cause and cardiovascular mortality in patients with end-stage renal failure³. Furthermore, Alx has been shown to be a strong independent risk marker for coronary artery disease⁴ and PWV has been shown to be an independent predictor of morbidity and mortality in hypertensive⁵ and diabetic patients⁶.

Increases in arterial stiffness cause an increase in myocardial demand and central systolic pressure along with a decrease in coronary artery perfusion pressure, thereby dramatically increasing the risk of heart attack, stroke and heart failure (to learn more about this mechanism see Reflection Presentation – provide link).

The SphygmoCor System analyses the blood pressure profile at the heart and provides important information on the clinical impact of arterial stiffness and wave reflection, allowing for an informed examination of cardiovascular risk. In addition, aortic arterial stiffness can be assessed with the SphygmoCor PWV.

Arterial stiffness is affected by and associated with many factors.

Age, Height and Gender

Advancing age is known to be an important determinant of cardiovascular risk⁷. With increasing age, large arteries progressively stiffen as well as dilate, resulting in an increase in systolic blood pressure and pulse pressure⁸ which can ultimately lead to conditions such as isolated systolic hypertension⁹, the most common form of hypertension in the elderly¹⁰. A number of studies have shown a positive association between arterial stiffness (aortic PWV and Alx) and age¹¹. Central pressure measurements (pulse pressure (PP), augmentation pressure (AP) and Alx) and aortic PWV all increase significantly with age, but Alx and PWV follow different patterns⁹. Changes in Alx have been shown to be more prominent in individuals below 50 years of age, whereas changes in aortic PWV are more marked in individuals over 50 years of age, while central PP and AP increase linearly with age. Central PP depends not only on stroke volume (a large determinant of peripheral PP) but also large artery stiffness and wave reflection. An increase in arterial stiffness with age leads to an increase in augmentation pressure and increase in systolic pressure (isolated systolic hypertension in the elderly). Therefore it has been suggested that to fully assess the impact of age and risk factors on large arteries, both PWV and central measures from PWA need to be assessed⁹. These normal reference ranges for both PWA and PWV are included in the SphygmoCor software enabling the physician to assess an individual patient's results against age- and gender-specific normal reference ranges.

Small stature has also been reported to be an independent risk factor for cardiovascular disease^{9,12}. To some extent this risk may be due to the shorter effective path length, which results in less distance for the pressure waves to travel, with resultant arrival of reflected waves earlier in the cardiac cycle (possibly while still in the systolic phase) causing an increase in central systolic pressure and left ventricular afterload¹².

Gender also plays a part in the extent of arterial stiffness with studies showing that healthy women have a significantly higher level of arterial stiffness than men^{9,13}. One explanation is the shorter average height of females, however when correcting for height gender still remains an independent predictor of Alx^{9,13}.

Cigarette Smoking

Due to its impact on endothelial function and vasoconstriction, smoking is a significant risk factor in the development and progression of cardiovascular disease¹⁴. Even in young people, Alx and PWV measures are significantly higher after smoking, as are central blood pressures¹⁵. In addition, baseline Alx measures are significantly higher in chronic smokers regardless of their gender or general health and fitness levels¹⁵.

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Despite these increases in central blood pressure, brachial BP is generally deceptively low in chronic smokers due to poor pressure amplification¹⁵. This illustrates the importance of the SphygmoCor System as the system gives true insight into aortic pressures and arterial stiffness.

It is well known that passive smoking has detrimental effects and increases the risk of heart attack and recent studies have highlighted the effects of passive smoking on arterial stiffness. These studies have shown that some levels of exposure to secondhand smoke have only a slightly less detrimental effect on arterial stiffness than smoking has.¹⁶ Other studies have also demonstrated the detrimental impact of cigar smoking on the stiffness of large arteries and wave reflection¹⁷.

Obesity

Obesity is becoming a global epidemic in both children and adults with the prevalence of overweight and obesity exceeding 60% of adults in the USA, and the rate is rapidly increasing in children and adolescents¹⁸. Obesity is an independent risk factor for cardiovascular disease and has also been associated with other conditions that carry a high cardiovascular risk, such as type 2 diabetes, hypertension and sleep apnea¹⁹. In recent years, it has been demonstrated that individuals with obesity are likely to have increased arterial stiffness, independent of brachial blood pressure, ethnicity and age²⁰. Central adiposity has been shown to be a significant determinant of Alx, independent of other factors such as age and mean arterial blood pressure and it has been suggested that it is important to look at the distribution of body fat in assessing systemic arterial stiffness, compared to overall body weight²¹. Aortic PWV has also been shown to be significantly associated with obesity and one study reported that median aortic PWV were 4–9 m/s higher in obese individuals compared to normal weight individuals²².

In addition, studies using the SphygmoCor system to assess endothelial function have shown obesity to be independently associated with endothelial dysfunction²³. Reducing visceral adiposity was associated with significant improvements in vascular endothelial function.

One of the common behavioural modifications prescribed for obesity is exercise. Exercise has been shown to reduce arterial stiffness in sedentary individuals⁹ and in patients with coronary artery disease²⁵ and end-stage renal failure²⁶. Exercise training improves arterial stiffness²⁵, which effectively reduces the risk of myocardial ischemia by decreasing their myocardial oxygen demand, and increasing coronary perfusion²⁵.

In addition, exercise may mitigate the arterial stiffening expected through the normal ageing process. Endurance trained individuals have been shown to have lower arterial stiffness, compared to sedentary individuals of the same age and blood pressure⁸, and

physical activity has been shown to lower the genetic expression for susceptibility to increased systemic arterial stiffness (Alx)²¹.

Cholesterol

High cholesterol levels have been shown to be associated with high central pulse pressures and systemic arterial and aortic stiffness, despite comparatively low peripheral blood pressures²⁷. In addition LDL cholesterol (but not HDL cholesterol) is an independent determinant of arterial stiffness, observed by an increase in Alx²⁷.

Lowering serum cholesterol level has been shown to reduce cardiovascular and total mortality²⁸, and reduction of cholesterol has been shown to be associated with a reduction in arterial stiffness²⁹. Statins have been shown to reduce aortic PWV over a 2 year period³⁰ and simvastatin, along with homocysteine with folic acid/Vitamin B12 are being studied in the SEARCH (Study of the Effectiveness of Additional Reductions in Cholesterol and Homocysteine) trial to assess whether there are beneficial effects with aggressive lipid lowering. Pulse wave analysis has been included in a Substudy of the SEARCH trial to assess whether there are beneficial effects on arterial stiffness³¹.

Diet

Achieving and maintaining a varied and healthy diet has been widely promoted to assist with good health. However there are many substances that are ingested that have profound effects on cardiovascular risk and arterial stiffness. A review of several of these that have been shown to have an affect on arterial stiffness and central blood pressure are highlighted below.

Caffeine

Caffeine is the most widely used pharmacologic substance in the world, and its effect on arterial stiffness can therefore not be overstated. A number of studies have shown ingestion of caffeinated coffee causes an increase in arterial stiffness^{21, 32, 33, 34 35} however a recent study showed that arterial stiffness did not increase when drinking decaffeinated coffee³³. Central systolic pressure and AP, along with the Alx have all been associated with coffee consumption, even after consumption of one cup, and without a similar increase in brachial blood pressure. In addition, caffeine and smoking have been noted to have a synergistic effect on arterial stiffness³⁶.

The detrimental effect of caffeine is also marked in treated hypertensive patients where it increased their aortic stiffness for a period of around 3 hours. The significance of this effect is worsened because in many cases, patients with hypertension already have a stiffer aorta than normotensive patients. Importantly, this highlighted that anti-hypertensive medication may not provide additional protection against the negative effects of caffeine³⁴.

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The effects of acute caffeine intake reveal an underlying and unfavourable effect on arterial stiffness and consequently left ventricular load, and it has been suggested that coffee consumption should be taken into consideration for reduction of cardiovascular risk³⁷.

Alcohol

It is known that the association between alcohol consumption and cardiovascular risk is 'U' shaped, with a higher risk in non-drinkers and heavy drinkers and a reduced risk in moderate drinkers. A recent study, showed that there is a similar 'U' shaped association with alcohol consumption and arterial stiffness (Alx)³⁸. Red wine ingestion in patients with coronary artery disease resulted in favourable effects on wave reflections and central systolic pressures, with no brachial blood pressure changes being observed³⁹. A similar result was also seen with de-alcoholised red wine³⁹. This study highlights the importance of measuring central pressures compared to conventional blood pressure when examining the effects of various agents on the cardiovascular system.

Dark Chocolate

A diet including high levels of flavonoid, as found in dark chocolate, has been reported to be beneficial to cardiovascular outcome. Consumption of dark chocolate has been shown to acutely decrease systemic arterial stiffness and wave reflections (Alx) and exert a beneficial effect on endothelial function, suggesting a beneficial effect on the cardiovascular system⁴⁰.

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