Central Aortic Blood Pressure and Cardiovascular Risk
A Paradigm Shift?

Alberto Avolio

The provocative proposition of “hypertension is a myth” has generated many a debate and editorial commentary. In contrast, the realities of high blood pressure and the associated cardiovascular risks have been ascertained from data obtained by the conventional brachial cuff sphygmomanometer. Notwithstanding the inherent limitations of the technique, there is yet no equivalent and suitable device that can be universally accepted to replace the cuff sphygmomanometer for practical and noninvasive measurement of arterial blood pressure in large population groups and with wide clinical applications. Attempts at complementing information obtained from cuff measurements have resorted to basic physiological studies in humans and experimental animals, which have shown that pulsatile blood flow in arteries can be described in terms of characteristics common to systems of wave propagation. These concepts explain the complex relationship between oscillatory blood pressure and flow, the difference in pressure wave shape, and the increase in pulse pressure between the aorta and peripheral arteries. Such wave propagation characteristics can be described in terms of mathematical entities known as transfer functions, with associated assumptions of stability and linearity.

The study by McEniery et al in this issue of Hypertension uses methodologies for both the cuff sphygmomanometer and transfer functions to determine central aortic pressure from the brachial cuff pressure measurement and the tonometric radial artery pressure pulse in >10 000 adults of age range 18 to 101 years. This is the largest study of its kind with conventional pressure measurements and pulse waveform data. The study allows analysis that can produce potentially groundbreaking results and poses important and possibly perplexing and challenging questions related not only to the role of central aortic pressure as an improved measure of the hemodynamic burden on the ejectional ventricle but also on the interpretation of guidelines for the management of hypertension as a cardiovascular risk factor with blood pressure as determined from the conventional brachial cuff.

One of the main features of this study is that it addresses the difference in pulse pressure between the site of conventional measurement and the central aorta. The ratio of aortic pulse pressure to brachial pulse pressure is independent of calibration and depends only on the reliable detection of the peripheral pressure pulse and the methodology used to estimate the central aortic pressure pulse. The tonometric sensor used by the investigators has been used extensively in many other studies over the last 2 decades and can detect highly accurate signals from the radial artery and show age-related changes in the arterial pulse wave shape in human population groups in the hands of adequately trained operators. The study by McEniery et al would seem to have satisfied this requirement. The cited study validating the use of the brachial transfer function shows close agreement between measured and estimated central pressure. The relevant and important feature of this validation study is that it was done with simultaneous invasive measurements of both radial artery pressure and aortic pressure, using manometer systems with a high frequency response and external pressure sensors, which were referenced to atmospheric pressure. Thus, the calibration was done with actual gauge pressures with no confounding factors related to the relative height of pressure sensors or other systematic or random errors, as can occur even with high-fidelity intravascular catheter-tip transducers. Hence, the methodology used in this validation study was a specific validation of the mathematical transfer function used to generate the central aortic pressure waveform. This is different from validating the technique using a noninvasive radial pulse calibrated with a sphygmomanometric cuff pressure (and with the inherent associated errors) and then comparing the estimated values with measured central aortic pressure, because this incurs the inherent calibration errors that are independent of the transfer function but are part of the chain of the system components.

The study found that, although the difference between peripheral and central pulse pressure decreases with age, it does not vanish in old age. It bottoms out in the age decade of 50 to 60 years, after which it is essentially constant, corresponding with an estimated average difference of 11 mm Hg in men and 8 mm Hg in women. Furthermore, for each age group, there is a considerable variability in the pulse pressure ratio. It is this variability that becomes relevant in determining the extent of overlap of central pressure values between the categories describing the various levels of blood pressure as defined by the recent European Society of Hypertension and of the European Society of Cardiology guidelines for management of hypertension. This is a crucial finding of the study, because the blood pressure bands in the guidelines are based entirely on the conventional measurement of brachial cuff pressure. Results indicate that, just on systolic values alone, there would be 32% of men and 10% of women who would be considered to have normal brachial systolic pressures and, therefore, not treated but would be classified as having stage 1 hypertension based on equivalent central aortic systolic pressure and, thus, would be
considered for treatment. The numbers are much more striking when comparing the high-normal category and stage 1 hypertension, with 78% of men and 63% of women who would be considered to be in the high reference range of systolic pressure but would be considered to be hypertensive based on equivalent central pressure values. Although these proportions can be quite striking in terms of those that could be exposed to cardiovascular risk and not detected or treated, the opposite is also true, because the overlap is also relevant to those who would undergo treatment based on cuff pressure values but would fall under a lower risk category when assessed in terms of central pressures (although the study does not report these proportions).

Recent studies have shown the importance of central aortic pressure and its implications in assessing the efficacy of antihypertensive treatment with respect to cardiovascular risk factors. Results of the study by McEniery et al highlight the issue of relating a measurement of brachial pressure to the categories in the guidelines, given this quite large range of overlap because of pulse amplification. The amplification is because of the frequency dependency of the transfer function, and because of the overall general stability of the transfer function, any difference in pulse amplification is attributable only to the frequency content of the pulse waveform, i.e., the waveshape. An important implication of this study is that, whereas sphygmomanometric cuff pressure will continue to be used as the most practical surrogate measure of arterial blood pressure, other useful and potentially highly relevant information may be obtained from the registration of the arterial pulse waveform. Furthermore, whereas central pressure values may be estimated with multiple regression models, including height, weight, heart rate, systolic and diastolic cuff pressure, and age, explain 76% of the variability. This agrees with the figure of 73% obtained in the study by McEniery et al and implies that the entire peripheral pulse waveform is required for a reliable estimation of central aortic pressure. This has further implications on the heart rate dependency on pulse amplification in individual pressure measurements and subsequent classification according to the guidelines.

The study by McEniery et al is timely, because there is a necessity to quantify the value of central aortic pressure, given the increasing interest in the field. The authors recognize some of the study limitations, such as its cross-sectional design, but the overall results indicate that it can form an important platform on which to launch further investigations on the relevance of central blood pressure. The study describes, for the first time, the unique feature of using the physiological phenomenon of the variable difference of the pulse pressure between the aorta and upper limb arteries. This is used to describe aging changes and to quantify the relevance of central aortic pressure estimated from measured values of conventional brachial cuff pressure.

A general question raised by the study of McEniery et al is whether this and other similar studies could lead to a type of paradigm shift in the understanding of the relevance of conventional blood pressure measurement by the introduction of central aortic blood pressure. There is no question that, with the introduction of the brachial cuff and auscultatory techniques, Drs Scipione Riva-Rocci and Nikolai Korotkoff caused a shift from essentially observation phenomena to quantification of the effects of blood pressure on cardiovascular disease by providing the ability to have numeric values for systolic and diastolic pressure and by the ubiquitous use of the sphygmomanometer throughout the 20th century. The addition, in the 21st century, of the earlier technology of sphygmoscopy, pioneered during the 19th century, could provide a practical and potentially more powerful means for a better stratification of cardiovascular risk. With respect to the mythological propositions of hypertension or high blood pressure, one could well recall the remark of an earlier gazer of the heavens in the early 17th century, who put into question the long established Aristotelian geocentric view of the universe, and, when taken away to be imprisoned, is said to have whispered, _sotto voce_, “E pur si muove!” Whether these words were actually uttered by Galileo Galilei or are entirely apocryphal, they do remind us that, whether we call it hypertension or high blood pressure, ultimately it is the truth that inevitably leads to paradigm shifts and not its mere perception from a distance.

**Disclosures**

None.

**References**

2. O’Rourke MF. Hypertension is a myth; higher arterial pressure is the problem. *Aust N Z J Med* 1984;14:69–70.