Hypertension Research (2011) 34, 164–165

www.nature.com/hr

COMMENTARY

# Measurement of arterial stiffness and wave reflections: does body position matter?

**Thomas Weber**

*Hypertension Research* (2011) **34,** 164–165; doi:10.1038/hr.2010.214; published online 4 November 2010

In recent years, arterial stiffness and arterial wave reflections have become a main focus of research in hypertension. The independent prognostic value of arterial stiffness (assessed as carotid–femoral pulse wave velocity, cfPWV) and, to a lesser degree, arterial wave reflections (assessed as central systolic pressure (CSP), augmentation index (Aix) and pressure augmentation (AP)) has been well established.[1,2] Moreover, at least in Europe, leading professional societies have recommended measurement of cfPWV in daily routine assessment of patients with arterial hypertension.[3] However, to serve as a diagnostic procedure, a large amount of basic work and standardization has to be carried out. In a previously published consensus document,[4] many important issues have been raised, and areas for future research have been identified. For example, the various methods for estimation of the distance traveled by the pulse wave when measuring cfPWV have been discussed, and studies published since then[5] have clarified the situation in a sense that the travel distance should be calculated on body surface as femoral–sternal notch distance minus carotid–sternal notch distance.[6] Furthermore, reference values in apparently healthy individuals could be established in large European populations.[7]

However, the important aspect of body position during the assessment of cfPWV seems to have been largely overlooked, with recommendations for preferring the supine position based on clinical wisdom[4,7] more than on published evidence. Although it may seem obvious that the supine position is advantageous for the commonly used tonometric method for cfPWV measurements (the femoral pulse wave cannot be recorded in the sitting position), this may not be true with newer devices aiming to determine PWV (as well as AIx) from oscillometrically recorded brachial pressure waveforms. When we consider body position for the assessment of AIx and CSP, the situation is even more complex: although the supine position may be preferred for stabilization of hemodynamics and for consistency (that is, following cfPWV measurement), there are strong arguments for the sitting position as well: basically, CSP is blood pressure, AP is blood pressure and AIx is a blood pressure ratio. There is unequivocal consensus among professional societies[3,8] that blood pressure measurements should be performed in the sitting position, resembling the way blood pressure is actually measured in clinical practice. But are these considerations important? The study by Nürnberger *et al.*[9] published in this issue of the Journal fortunately provides an important piece of evidence: in this study, CSP, AIx and PWV were measured in 24 healthy volunteers and 20 patients with cardiovascular disease three times in the supine and three times in the sitting position. The main study result was that—according to Pearson's correlation coefficient and Bland–Altman plots—values for PWV and AIx showed good agreement between the supine and the sitting positions, leading to the conclusion that PWV (obtained with oscillometric devices) and AIx (with tonometric and oscillometric devices) can be measured reliably in the sitting position.

Are the findings physiologically plausible? It is well known that body posture has a small but not negligible influence on blood pressure and wave reflection characteristics: in a previously reported study, posture-related changes of carotid waveforms and blood pressure were investigated.[10] Compared with the supine position, in the sitting position diastolic blood pressure and heart rate increased significantly (reflecting normal

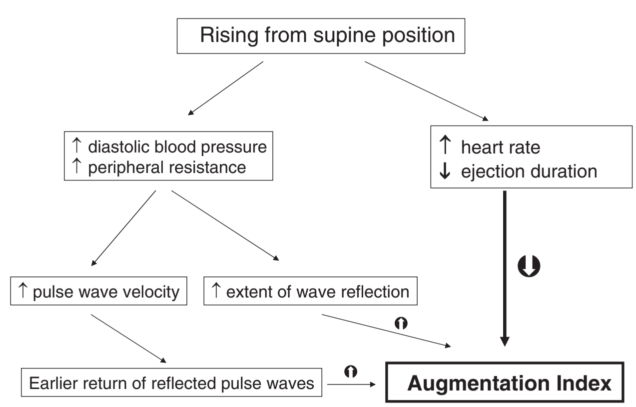


**Figure 1** Hemodynamic changes with rising from the supine position. In the sitting position, the changes may be of borderline significance. With standing and head-up tilting, the shortening of ejection duration will be the overriding factor, leading to a decrease of Augmentation Index mainly due to arrival of the reflected waves later in systole and ultimately after aortic valve closure.

Professor T Weber is at the Cardiology Department, Klinikum Wels-Grieskirchen, Grieskirchnerstrasse 42, Wels 4600, Austria.
E-mail: thomas.weber3@liwest.at

baroreflex activation). Probably due to increased PWV (which was not measured in that study), reflected pulse waves returned earlier at the carotid site, which was significantly correlated with the shorter ejection period. These two observations theoretically would exert opposite changes on AIx (higher with earlier returning reflected waves, but lower with higher heart rates) and, thus, minimize any posture-related changes. Overall, the findings were replicated in the Nürnberger study: with rising from the supine to the sitting position, diastolic blood pressure and heart rate increased significantly, whereas PWV and AIx showed a trend toward an increase. If a higher orthostatic stress in applied (for example, during head-up tilt test), the changes in heart rate and ejection duration become the overriding factors determining the changes in AIx: despite an increase in diastolic blood pressure (with consecutive increase in PWV, decrease in reflection time and earlier arrival of reflected pressure waves from the periphery) and in peripheral resistance (with consecutive increase in impedance mismatch and increase in the extent of wave reflection), both factors rising AIx, the shorter ejection duration (leading to arrival of reflected waves later in the cardiac cycle) will lead to a lower AIx due to altered matching of the primary and the reflected pressure wave[11] (Figure 1).

But with the smaller hemodynamic changes, when comparing only the supine and the sitting positions, differences are smaller and—in fact—may be considered negligible for measurements in clinical routine. But before this conclusion can be drawn safely, some questions have to be answered:

*Regarding PWV*: How accurate are the values obtained with the newer oscillometric devices, when compared with the noninvasive standard tonometric system[6]? Based on the Bland–Altman plots, in the Nürnberger study the Arteriograph system seems to meet published criteria for 'acceptable' accuracy,[6] which is in line with a recently reported invasive validation study.[12] As to the Vascular Explorer system, Bland–Altman plots in comparison with the tonometric system are compatible with systematic bias. Moreover, for both oscillometric systems, clinical validation (that is, based on clinical outcomes) is lacking.

*Regarding AIx*: Is the clinical information derived from AIx and CSP (for example, regarding pathophysiology, prognosis and drug effects) comparable when measured in the supine *vs*. sitting position? Ideally, head-to-head studies where both are measured should be performed.


1 Vlachopoulos C, Aznaouridis K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. *J Am Coll Cardiol* 2010; **55**: 1318–1327.
2 Vlachopoulos C, Aznaouridis K, O'Rourke MF, Safar ME, Baou K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with central hemodynamics: a systematic review and meta-analysis. *Eur Heart J* 2010; **31**: 1865–1871.
3 Mancia G, De Backer G, Dominiczak A, Cifkova R, Fagard R, Germano G, Grassi G, Heagerty AM, Kjeldsen SE, Laurent S, Narkiewicz K, Ruilope L, Rynkiewicz A, Schmieder RE, Boudier HA, Zanchetti A, ESH-ESC Task Force on the Management of Arterial Hypertension. 2007 ESH-ESC Practice Guidelines for the Management of Arterial Hypertension. *Eur Heart J* 2007; **28**: 1462–1536.
4 Laurent S, Cockcroft J, Van Bortel L, Boutouyrie P, Giannattasio C, Hayoz D, Pannier B, Vlachopoulos C, Wilkinson I, Struijker-Boudier H, European Network for Non-invasive Investigation of Large Arteries. Expert consensus document on arterial stiffness: methodological issues and clinical applications. *Eur Heart J* 2006; **27**: 2588–2605.
5 Weber T, Ammer M, Rammer M, Adji A, O'Rourke MF, Wassertheurer S, Rosenkranz S, Eber B. Noninvasive determination of carotid–femoral pulse wave velocity depends critically on assessment of travel distance: a comparison with invasive measurement. *J Hypertens* 2009; **27**: 1624–1630.
6 Wilkinson IB, McEniery CM, Schillaci G, Boutouyrie P, Segers P, Donald A, Chowienczyk PJ. ARTERY society guidelines for validation of non-invasive haemodynamic measurement devices: part 1, arterial pulse wave velocity. *Artery Res* 2010; **4**: 34–40.
7 The Reference Values for Arterial Stiffness Collaboration. Determinants of pulse wave velocity in healthy people and in the presence of cardiovascular risk factors: 'establishing normal and reference values'. *Eur Heart J* 2010; **31**: 2338–2350.
8 Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo Jr JL, Jones DW, Materson BJ, Oparil S, Wright Jr JT, Roccella EJ. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension* 2003; **42**: 1206–1252.
9 Nürnberger J, Michalski R, Türk TR, Opazo Saez A, Witzke O, Kribben A. Can arterial stiffness parameters be measured in the sitting position? *Hypertens Res* 2011; **34**: 202–208.
10 Reesink KD, Hermeling E, Hoeberigs MC, Reneman RS, Hoeks AP. Carotid artery pulse wave time characteristics to quantify ventriculoarterial responses to orthostatic challenge. *J Appl Physiol* 2007; **102**: 2128–2134.
11 Tahvanainen A, Koskela J, Tikkakoski A, Lahtela J, Leskinen M, Kähönen M, Nieminen T, Kööbi T, Mustonen J, Pörsti I. Analysis of cardiovascular responses to passive head-up tilt using continuous pulse wave analysis and impedance cardiography. *Scand J Clin Lab Invest* 2009; **69**: 128–137.
12 Horváth IG, Németh A, Lenkey Z, Alessandri N, Tufano F, Kis P, Gaszner B, Cziráki A. Invasive validation of a new oscillometric device (Arteriograph) for measuring augmentation index, central blood pressure and aortic pulse wave velocity. *J Hypertens* 2010; **28**: 2068–2075.