Calibration of Noninvasively Recorded Upper-Limb Pressure Waves

To the Editor:

The article by Verbeke et al1 raises an important question: how does one calibrate the radial artery waveform obtained by applanation tonometry? Does one apply systolic and diastolic brachial values from the Korotkov technique, the “gold standard”, or does one use an oscillometric wrist technique, despite lack of confidence in any available method? Alternatively, as implied by Verbeke et al, should one use brachial tonometry instead, calibrated to brachial-cuff values?

The study by Verbeke et al1 suggests (from noninvasive methods alone) that the present technique of calibrating radial tonometry to brachial-cuff pressure may have substantial inaccuracy. The method by Verbeke et al1 depends on a technique originally described by Kelly and Fitchett2 where systolic pressure was extrapolated on the assumption that diastolic and mean pressure were identical throughout the arterial tree. The technique currently recommended in the SphygmoCor process is based on invasive studies of arterial pressure waves, which showed that amplification between brachial and radial artery is small in comparison to that between aorta and brachial artery.3,4

We repeated essentials of the Verbeke et al1 study and confirmed estimation of high pressure amplification between brachial and radial sites. But in the process we became aware of several technical factors that could account for the estimations and, hence, regard these as flawed. First, we could not be confident of successfully applanating the brachial artery. Unlike carotid and radial arteries, the brachial has no support behind so the artery surface cannot confidently be flattened when the tonometer is applied. Second, the artery is deeper than the radial, and often covered by part of the bicipital aponeurosis, so the tonometer had to sense through this. We and others have been able to confirm similarity of tonometric and invasive waveforms at carotid and radial sites,4,5 but there are no such confirmatory data for the brachial site. Our brachial tonometry waveforms were more blunted than when recorded directly by needle or cannula. We did show reasonable accuracy of the Kelly/Fitchett extrapolation technique for systolic pressure when a more blunted systolic peak was calculated from a sharper peak (ie, carotid from radial pulse), but not when the process was reversed, as in noninvasive estimation of radial peak from brachial peak, on which Verbeke et al1 relied.1

We acknowledge inaccuracy of all cuff methods for measuring systolic and diastolic pressure within an artery, but agree that some are better than others. Radial sphygmography and tonometry are supported by precedent, theory, and practice, whereas brachial tonometry is suspect. Radial tonometry can provide useful information on contour of the aortic waveform including ejection duration and augmentation index, even without calibration. If calibration is to be used, we believe that the presently accepted brachial-cuff technique using the Korotkov method is still preferable to any wrist-cuff method.

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Response

The important question raised by O’Rourke of whether local brachial artery (BA) waveforms are reliable cannot be answered unequivocally because no invasive data are currently available. Theoretically, tonometry signals can be acquired at any superficial arterial site, including the radial, carotid, brachial, and femoral artery, as has been done in a large sample of the Framingham Offspring population.1 The BA is superficial throughout its entire extent, and although initially it lies medial to the humerus, as it runs down the arm it gradually gets in front of the bone.2 This makes the BA (just proximal of the bend), on purely anatomic grounds, suitable for applanation tonometry although we agree that in certain subpopulations, such as very obese individuals or those with large biceps muscles, adequate BA tonometric waves are difficult to obtain. However, the same limitation also applies to carotid artery tonometry for obese subjects and those with a short neck, and to radial artery tonometry for female patients with tiny arteries where one can easily exert too much pressure.

Somewhat corresponding to the bluntness of the curve mentioned by O’Rourke is the SphygmoCor’s quality criterion (developed for radial artery waves) of a minimum dP/dt (ie, a minimum initial rise in pressure for a given time). In our study, all measurements passed this quality control (mean value 659±155). Also, the mean arterial pressure (MAP) calculated from the BA systolic (SBP) and diastolic blood pressure (DBP) by the formula MAP = 1/3(SBP + 2/3(DBP) yielded values (87.0 mm Hg) similar to those obtained by BA tonometry (88.8 mm Hg). Although we acknowledge the limitation of this formula, important errors in the acquisition of the BA waveforms would probably have generated lower tonometric values (and not higher).

If the BA tonometric waveforms and their derived radial and central systolic pressures would be inaccurate, then we would also expect an important error in the aorta-to-radial pressure amplification. We observed an 8.9±6.6 mm Hg systolic pressure difference between carotid and radial artery and an estimated (SphygmoCor) aorta-to-carotid difference of 2.1±2.6 mm Hg, yielding an aorta-to-radial systolic pressure amplification of 11.4±7.8 mm Hg, which is in agreement with the invasively recorded aorta-to-radial amplification of 12.0±1.0 mm Hg reported by Fauca.3

We4 and other authors1 have been successful in obtaining BA tonometric waves that meet certain quality control parameters in different populations, including healthy persons, dialysis patients, and renal transplant recipients (Verbeke et al, unpublished data, 2004). In the renal population, BA tonometry may be of
particular value because some patients have undergone vascular surgery at both radial arteries in an attempt to create a successful vascular access for dialysis. Like many noninvasive procedures, however, the recording and appraisal of an adequate tonometric waveform (at the brachial as well as at the radial and the carotid artery) to some extent remains also dependent on the technical expertise and judgment of the operator.

Only invasive studies will be able to provide definite proof whether BA applanation tonometry can be used as a valid approximation of the intraarterial pressure waveform.

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