Ahead of the Curve

Waveform Analysis of Blood Pressure, Reflection Magnitude, and Outcomes

Alun D. Hughes

See related article, pp 958–964

The history of blood pressure (BP) waveform analysis is almost as undulatory as the waveform itself. The development of the sphygmograph in the mid-19th century led to a relatively brief, albeit intense, interest in the interpretation of the BP waveform.1 This was perhaps more an art than a science, and interest in the sphygmograph and the waveform declined after the introduction of the cuff-based sphygmomanometer. More recently, interest in pulse waveform analysis has re-emerged, and the relative merits of estimated aortic (central) as opposed to brachial systolic and pulse pressure have been widely discussed. Although some issues remain unresolved, evidence from systematic reviews suggests that central pulse pressure may be a better predictor of cardiovascular events2 as opposed to brachial systolic and pulse pressure that have been widely discussed. Although some issues remain unresolved, evidence from systematic reviews suggests that central pulse pressure may be a better predictor of cardiovascular events2 and that central BP can be differentially modified by antihypertensive therapy, with β-blockers being comparatively less effective on central than peripheral BP.3 However, whatever the merits of measurement of central systolic or pulse pressure, a single number is unlikely to be an adequate descriptor of the morphology of a waveform, and the waveform may contain additional valuable and quantifiable information.

In this issue, Zamani et al4 report the results from ~6000 participants in the Multi-Ethnic Study of Atherosclerosis (MESA). BP waveforms were recorded using a noninvasive radial tonometric device and analyzed using a technique that separates them into forward (Pf) and backward (Pb) components. Reflection magnitude (RM) was calculated as the ratio of peak Pf/peak Pr. RM and Pb were found to predict all-cause mortality, cardiovascular mortality, and noncardiovascular mortality in unadjusted models. Notably, the association with all-cause mortality was independent of a wide range of measures of subclinical atherosclerosis. These findings extend previous data from MESA where RM predicted cardiovascular end points and was strongly predictive of new-onset chronic heart failure.5 Associations between cardiovascular events and RM and Pb have also been observed in a study of 725 patients (55–72 years) undergoing coronary angiography6 and between reflection index (RM/[1+RM]) and Pb in another study of 1272 individuals (30–79 years) drawn from a community-based survey in Taiwan.7 The results of these studies seem reasonably consistent (Figure).

Some technical considerations regarding the approach used by Zamani et al4 and in other studies are worth consideration. Strictly, pressure separation requires measurement of both pressure and flow waveforms at a given location. Zamani et al4 circumvented the requirement for flow measurement by using a scaled representative average aortic velocity waveform derived from the Asklepios population-based study. Other studies have used an estimate of aortic flow based on a Windkessel model8 or have assumed a triangular shape for aortic flow.7 Whichever assumption is used will introduce some uncertainty into the estimates of Pb and Pr. A previous study by Kips et al9 suggests that the correlation between RM calculated using average and measured waveforms is good (r²=0.74) but not perfect. Zamani et al4 also used a generalized transfer function to approximate the aortic BP waveform. This is a widely accepted approach, and most published transfer functions are similar; nevertheless, the use of a generalized transfer function will introduce further variability into the reconstructed aortic BP waveform. Imprecision in the pressure and flow waveform estimates should not introduce systematic bias, but will tend to weaken associations seen, so it is likely that the estimates of association between RM or Pb and outcomes are underestimates of true relationships. Together, the limited published studies so far suggest that these indices are likely to add to the predictive information obtained by BP measurement. In their earlier study, Chirinos et al3 reported that adding RM to a model containing age, sex, body mass index, diabetes mellitus, and BP resulted in a category-free net reclassification index of 0.38 and achieved a 48% relative increase in the discrimination slope. It would be valuable to know to what extent measurement of RM and Pb improves reclassification of risk in other populations.

As yet, estimates of RM and Pb in relation to mortality or cardiovascular events have been performed using radial or carotid tonometry; however, these indices can be calculated by cuff-based oscillometric devices.10 The extent of agreement between different devices and locations has not been studied for RM and Pb, but there is evidence that estimates of central BP differ depending on the device or location used.11 This issue merits further study. Undoubtedly, there are clear advantages in using cuff-based devices in terms of familiarity and convenience in clinical practice. All oscillometric devices

The opinions expressed in this editorial are not necessarily those of the editors or of the American Heart Association.

From the Institute of Cardiovascular Science and National Institute for Health Research, University College London Hospitals Biomedical Research Centre, University College London, London, United Kingdom. Correspondence to Alun Hughes, Institute of Cardiovascular Science, 170 Tottenham Court Rd, University College London, London W1T 7HA, United Kingdom. E-mail alun.hughes@ucl.ac.uk


Hypertension is available at http://hyper.ahajournals.org
DOI: 10.1161/HYPERTENSIONAHA.114.03998

929
record the pressure waveform, so it would seem possible that this type of approach could be generalized to any such device.

Finally, pressure separation is not the only waveform-based approach currently being studied as a predictor of risk. Other approaches based on Windkessel-type models have been described.12,13 Future studies should examine how the various different waveform-based approaches compare in terms of risk prediction and risk classification.

Sources of Funding

A. Hughes receives support from the National Institute for Health Research University College London Hospitals Biomedical Research Centre.

References


Disclosures

A. Hughes has received minor support (equipment loans) from Esaote, Hitachi Medical Systems, Industrielle Entwicklung Medizintechnik und Vertriebsgesellschaft mbH, and USCOM.

Hypertension
November 2014
Ahead of the Curve: Waveform Analysis of Blood Pressure, Reflection Magnitude, and Outcomes
Alun D. Hughes

Hypertension. 2014;64:929-930; originally published online August 4, 2014;
doi: 10.1161/HYPERTENSIONAHA.114.03998

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://hyper.ahajournals.org/content/64/5/929