How to Best Assess Blood Pressure?
The Ongoing Debate on the Clinical Value of Blood Pressure Average and Variability

George S. Stergiou, Gianfranco Parati

See related article, pp 1087–1093

It is half a century since high blood pressure (BP) measured in the doctor’s office has been proved to be a strong predictor of cardiovascular morbidity and mortality. However, it soon became clear that multiple factors can significantly affect the BP measurement result (Table 1) and may thereby have considerable impact on its prognostic ability.

Despite the intensive research with almost 120,000 PubMed papers on issues related to BP monitoring, the question “how to best assess BP” is still a matter of hot debate. Notwithstanding these difficulties, research in the field of BP monitoring has considerably refined the BP measurement procedure, by systematically addressing all factors listed in Table 1. Such improvement has included a better standardization of methods as well as the development of multiple approaches to BP quantification, aiming to more precise risk prediction. This was achieved not only by a more accurate estimation of mean BP, but also by the evaluation of different patterns of BP variation over time. Although, irrespective of the measurement methodology (Table 1), any BP value is by itself a powerful index of risk, several aspects of BP dynamics assessed by considering patterns of BP change over time have been proved to increase the prognostic ability of BP, over and above the information provided by conventional office measurements.

Practicing physicians, as well as patients themselves (particularly those self-monitoring their BP at home), are frequently concerned by the possibility that BP fluctuations occurring in daily life, which often rise well above the average BP level, might cause additional hemodynamic stress on the heart and vasculature, increasing thereby the risk of organ damage. Indeed, the frequent occurrence of BP fluctuations, sometimes of non-negligible magnitude, is evident with large deviation away from the average are usually regarded as “random” and “noise” and are ignored.

In this issue of the journal, Matsui et al. provide evidence that in untreated hypertensives the maximum systolic BP value of 14-day home monitoring is more closely related with cardiac and vascular damage than average home BP. Moreover, maximum home BP showed independent predictive ability for target organ damage, beyond that of average home BP. In a recent retrospective analysis by Rothwell et al., maximum BP assessed by office measurements was also a strong predictor of stroke independently of the mean BP. In the same line, a study in acute ischemic stroke showed that the maximum BP assessed during the first 3 days in hospital was closely associated with the risk of developing hemorrhagic transformation independently of the mean BP. Thus, occurrence of BP peaks, wherever assessed (office, home, or hospital), appears to provide independent prognostic information beyond that of average BP. These data are supported by reports on the association between the morning surge in BP above that of average BP, this issue largely remains an interesting hypothesis only, and in clinical practice BP values with large deviation away from the average are usually regarded as “random” and “noise” and are ignored.

Table 1. Aspects of the BP Measurement That Might Influence Its Assessment

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Different Approaches Affecting the BP Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td>Office, work, ambulatory, home</td>
</tr>
<tr>
<td>Time</td>
<td>Daytime, nighttime, nocturnal dip, morning, evening, morning surge, postprandial</td>
</tr>
<tr>
<td>Observer</td>
<td>Doctor, nurse, technician, relative, self-measurement, automated</td>
</tr>
<tr>
<td>Device</td>
<td>Mercury, aneroid, hybrid, oscillometric</td>
</tr>
<tr>
<td>Posture</td>
<td>Basal, lying, seated, standing, exercise</td>
</tr>
<tr>
<td>Reading</td>
<td>First reading, first day, first visit, several measurements</td>
</tr>
<tr>
<td>Calculation</td>
<td>Average, variability, reactivity, maximum</td>
</tr>
</tbody>
</table>

Table 2. Measures of BP Variability, Instability, and Reactivity

<table>
<thead>
<tr>
<th>Variability</th>
<th>Short term: reading-to-reading (ambulatory monitoring)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium term: day-to-day (home monitoring)*</td>
<td></td>
</tr>
<tr>
<td>Long term: visit-to-visit (office measurements)*</td>
<td></td>
</tr>
<tr>
<td>Instability</td>
<td>Maximum BP: office, home, ambulatory monitoring*</td>
</tr>
<tr>
<td>Morning BP surge: ambulatory monitoring*</td>
<td></td>
</tr>
<tr>
<td>Reactivity</td>
<td>Physical tests: isometric or isotonic exercise testing,*</td>
</tr>
<tr>
<td>cold pressor test, etc.</td>
<td></td>
</tr>
<tr>
<td>Mental tests: arithmetic task, reaction time task, psychologic and emotional challenges, mental stressor test, etc.</td>
<td></td>
</tr>
</tbody>
</table>

*Shown to be associated with target organ damage or cardiovascular events.

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

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and the morning prevalence of cardiovascular events, an association that becomes closer when the morning BP surge is particularly pronounced. Indeed, it has been shown that whatever the time of the day when a BP surge occurs, either in the morning after nighttime sleep or in the afternoon after siesta, a parallel surge in stroke events also occurs. These data imply that peaks in BP (maximum or surge after sleep) might trigger cerebrovascular events.

Transient and episodic BP elevations are indices of BP instability (Table 2) and contribute to overall BP variability. Several other aspects of BP variability, eg, reading-to-reading, day-to-day, and visit-to-visit fluctuations, assessed by ambulatory, home, and office measurements, respectively, have all been shown to give prognostic information, independent of that provided by average BP values. However, these different components of BP variability may reflect different mechanisms, are likely to provide different information on cardiovascular regulation, and thus may carry different clinical implications still poorly understood. On one hand, BP variation within a 24-hour period may depend on central and reflex neural mechanisms, being importantly modulated among other factors by acute response to environmental stress and by arterial baroreflex influences. On the other hand, day-to-day and visit-to-visit BP differences, after taking into account differences in measurement procedures and environmental conditions, are more likely to depend on BP instability due to a variable integration of multiple cardiovascular control mechanisms while facing common daily life challenges. Moreover, in treated patients, an important determinant might also be a variable daily compliance with treatment. In a retrospective analysis of the Anglo-Scandinavian Cardiac Outcomes Trial Blood Pressure Lowering Arm (ASCOT-BPLA), visit-to-visit variability assessed by office measurements had a larger effect on vascular events than reading-to-reading variability assessed by ambulatory monitoring. It has to be considered, however, that because of methodological limitations, the ASCOT-BPLA analysis had to rely on between-subjects BP variation, which was arbitrarily taken as surrogate measure of within-subjects BP variability. These data are in disagreement with previous studies in patient cohorts and general population samples showing short-term BP variability assessed by ambulatory monitoring to provide significant contribution to risk stratification of or beyond the average ambulatory BP. With regard to home measurements, in the Ohasama study, increased home BP variability was associated with significant increase in stroke mortality, yet a comparison with office or ambulatory BP variability was not provided.

The issue of BP variability is not new. In 1987, Parati et al showed that for nearly any level of mean 24-hour BP assessed intra-arterially, subjects with high BP variability had more severe target organ damage, an observation confirmed by long-term follow-up in the same patients. The recently reported additional data on BP variability and instability now call for further research. In particular, the data by Rothwell et al showing that different antihypertensive drugs might differently affect BP variability, which might influence their contribution to cardiovascular protection, need adequate confirmation by properly designed studies and, if confirmed, should lead to urgent translation and action into clinical practice.

On such a complex background, it is difficult to identify the optimal strategy for taking BP variability and instability into account in routine practice. While waiting for future evidence-based recommendations, a few simple practical indications might, however, be given. Whatever BP measurement technique is used, focus should always be on repeating measurements over time and combining office and out-of-office readings. Such an approach provides information on both BP average levels and fluctuations over a given time window. Given the wide availability of home BP monitors worldwide and their good acceptance by patients for repeated measurements, home monitoring appears to be the most feasible method for first-line assessment and long-term monitoring of BP variability and instability in clinical practice. At the same time, however, an increasing use of ambulatory monitoring is needed to provide complementary information on BP variability over 24 hours.

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None.

**References**

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