Blood Pressure Measurement:

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ABSTRACT: The most common errors in measuring blood pressure (BP) are using the incorrect cuff size, not having the patient relax for 5 minutes before the measurement, and deflating the cuff too quickly. Observer bias may compound technical errors. When patients use the proper procedure, home BP measurements may be more reproducible than office measurements. Brachial artery-based monitors are more accurate than finger- or wrist-based instruments. To ensure that patients measure their BP correctly, observe their technique with their own monitors. Counsel patients to measure their BP at predetermined times and to have their monitors validated periodically.

Blood pressure (BP) measurement is an essential component of most adult office visits—particularly because 20% to 40% of these visits are related to hypertension. Although the American Heart Association (AHA) and other organizations offer guidelines for accurate BP measurement, there is evidence that these recommendations often are not followed. BP readings may be significantly affected by seemingly trivial distractions, such as talking, or by incorrect positioning. The errors introduced by poor technique may appear minimal in individual cases, but the cumulative effects may be substantial. As small an increase as 5 mm Hg in diastolic BP (DBP) readings would significantly increase the number of persons classified as hypertensive. Mistakes in technique may be compounded by other errors, such as terminal digit preference (eg, home BP readings are consistently rounded off to zero) and observer bias. Because of the frequency of error and the potential impact of misdiagnosis-in addition to the inherent variability of BP—attention to the details of proper technique is crucial.

In this article, we review current guidelines for BP measurement, with an emphasis on common pitfalls and how they may be avoided. We also address the implications of the growing use of home and ambulatory BP monitoring.

AN EARLY INNOVATOR
In 1905, Nikolai Korotkoff described the onset and disappearance of sounds heard during auscultation of the brachial artery while occlusive pressure is withdrawn. These subsequently became known as Korotkoff sounds and have since served as estimates of systolic (onset) and diastolic (disappearance) pressure (Table 1). Although Korotkoff sounds underestimate systolic BP (SBP) by 3 mm Hg and overestimate DBP by 6 to 8 mm Hg, they are considered the most reliable indicators of these pressures in outpatient medicine. Their prognostic value over the last century as markers of actual and impending cardiovascular disease has been thoroughly documented.

CORRECT TECHNIQUE
The most accurate BP measurements are obtained when the techniques and conditions used in clinical studies are closely emulated. The following steps have been compiled from published guidelines and from our experience in a hypertension clinic. Following these steps ensures that BP measurement closely duplicates the procedure used in most of the studies that have demonstrated the association between clinical (particularly cardiovascular) end points and BP elevation.

Before the reading. Advise patients to avoid caffeine and nicotine for 30 minutes beforehand, because these agents can raise BP. A full bladder also stimulates BP elevation because of increased sympathetic activity. Ensure that the patient has rested comfortably in a quiet room without distractions for approximately 5 minutes. To minimize pressure elevation from isometric contractions, seat the patient with legs and back supported. In one study, lack of back support raised DBP 6 mm Hg; SBP was unchanged.

The appropriate instrument. Use a cuff whose inflatable portion surrounds at least 80% of the circumference of the arm. False elevations in pressure result from the use of cuffs that are too small, because such cuffs require an excessive amount of internal pressure to occlude the brachial
The lower edge of the cuff should be 2 to 3 cm above the antecubital fossa. Use a mercury sphygmomanometer if one is available. Although an aneroid manometer may be as accurate as the mercury device and is an acceptable alternative, it may be less reliable because of the need for frequent calibration. Studies have shown 40% of aneroid sphygmomanometers to be out of calibration by 4 mm Hg or more (with 30% off by 10 mm Hg or more), compared with 8% of mercury devices. As the use of mercury-based sphygmomanometers decreases, it is essential to ensure that aneroid devices undergo regular calibration and maintenance. One program recently demonstrated that this can be done successfully.

Proper arm position. Measure BP in the dominant arm, with the upper arm angled so that the stethoscope is at approximately the level of the heart. This will usually require placing something firm under the patient's elbow to support and elevate the arm. You can also rest the patient's elbow in your hand, although the same hand is needed to hold the stethoscope. A phlebotomy chair or appropriately elevated table may also be used. Measure BP in the nondominant arm at least once and take the pressure in the arm with the higher pressure in subsequent measurements.

Palpation and auscultation. Palpate the brachial artery before auscultation and inflate the cuff by increments of 10 mm Hg at a time to a value 30 mm Hg over the pressure at which the radial pulse disappears. The point of disappearance and subsequent reappearance of the pulse during deflation approximates systolic pressure. This maneuver helps evaluate the presence of an auscultatory gap—the occasional disappearance of Korotkoff sounds after phase I. If you inflate the cuff during auscultation to the point of absent Korotkoff sounds while listening over the artery without previous palpation, you may mistake phase II for phase I and significantly underestimate systolic pressure. Place the bell of the stethoscope over the brachial artery superior and medial to the antecubital fossa, where the brachial artery pulse is most intense to palpation. Some question exists as to whether the bell should be used instead of the diaphragm, although the bell is thought to reproduce more accurately phase IV and V Korotkoff sounds.

Auscultate the brachial artery, with the arm in a supported position and the cuff at heart level. Inflate the cuff to 30 mm Hg above the level of SBP previously estimated by palpation. Deflate the cuff at a rate of 2 mm Hg/s. More rapid deflation decreases your ability to note changes in Korotkoff sounds, and significantly slower deflation may increase venous congestion in the arm and raise the diastolic value.

Noting the measurements. Record, to the nearest 2 mm Hg, the level at which the first of 2 consecutive sounds is heard. (Accuracy greater than to within 2 mm Hg cannot be obtained by either a mercury sphygmomanometer or an aneroid device.) Odd-numbered readings on the patient's chart point to use of automatic recording devices or to significant observer error. Note the level at which sounds become muffled (phase IV) and disappear (phase V). If sounds continue toward zero, note this as well.

AVOIDING PITFALLS
A 1990 study found the most common errors to be:
- Use of the wrong-sized cuff.
- Failure to have the patient relax for 5 minutes.
- Too rapid deflation of the cuff.
These findings have been confirmed in more recent studies. Tips on ensuring the accuracy of BP measurement are listed in Table 2.

A recent review summarized the effects of various activities on BP. The authors note that:
- Talking elevates SBP 17 mm Hg and DBP 13 mm Hg.
- Acute exposure to cold elevates SBP 11 mm Hg and DBP 8 mm Hg.
- Arm placement 10 cm below the level of the heart increases SBP and DBP 8 mm Hg; arm placement 10 cm above the level of the heart decreases SBP and DBP 8 mm Hg.
- Lack of arm support increases SBP and DBP about 2 mm Hg.
- An inappropriately small cuff lowers SBP 8 mm Hg and raises DBP 8 mm Hg.

Another study found that the white coat effect (the nonspecific elevation in BP that many persons experience when they enter a medical setting) can raise SBP by 11 to 28 mm Hg and DBP by 3 to 15 mm Hg.

HOME AND AMBULATORY BP MEASUREMENT
Home and ambulatory BP monitors are increasingly used in the management of hypertension. These instruments are particularly helpful in determining whether a patient has white coat hypertension and in assessing the response to therapy. When taken correctly, home BP measurements may be more reproducible than office measurements.

Home and ambulatory devices record BP by auscultatory discrimination or oscillometric assessment.
The latter technique recognizes mean arterial pressure based on the maximum recorded oscillation. Systolic and diastolic blood pressure are subsequently determined by algorithm. Oscillometric devices may not measure pressures accurately in patients with arrhythmias, particularly atrial fibrillation.

**Home BP monitors.** The benefit of these instruments is obviated if they are not reliably accurate and if patients do not use them correctly. A number of home and ambulatory devices were tested recently by researchers who used American and British assessment guidelines. The findings support the well-recognized limitations of wrist- and finger-based readings. Most experts recommend brachial artery-based monitors. Advise patients to purchase devices that meet international standards, such as those listed on the Web site of the British Hypertension Society: www.hyp.ac.uk/bhsinfo/bpmdigit.html. The use of incorrect technique to measure BP at home is a widely underappreciated problem. The same careful procedures need to be followed in home measurement as in clinic measurement. These include limiting activity for a set period before the reading, keeping the arm at heart level, and not talking during the procedure. We ensure that patients are using the correct technique by having them perform the measurement with their own device under our supervision. Counsel patients to measure their BP at predetermined times, not just when they are feeling well or unwell. Remind them that the accuracy of all devices should be independently validated periodically. At our clinic, we have patients bring their monitors in annually for calibration against mercury devices, unless an earlier calibration is warranted.

**Ambulatory monitors.** These devices are particularly useful in diagnosing suspected white coat hypertension in patients who have no signs of target organ damage. Approximately 10% to 40% of normotensive and nominally borderline hypertensive patients experience an appreciable white coat effect, and many may be erroneously classified as hypertensive. However, there is concern about ongoing target organ damage, particularly left ventricular hypertrophy, in untreated patients with white coat hypertension.

Ambulatory monitoring may be useful in other areas of hypertension. Differentiating "dippers" (those whose BP falls during sleep) from "nondippers" may allow earlier identification of persons at increased risk for target organ damage. A recent study showed a higher prevalence of left ventricular hypertrophy and carotid intima-media thickening among nondippers in whom hypertension had recently been diagnosed. Future research may determine whether pharmacologic therapy based on dipping status is appropriate.

Home BP readings average 5/5 mm Hg lower than office readings. Although there is no definitive consensus, most experts agree that the upper limits of normal for ambulatory daytime measurements should range from 129 to 135 mm Hg for SPB and 79 to 85 mm Hg for DBP. Normal nocturnal pressures should be lower. This topic has been extensively reviewed elsewhere. New prognostic data show that ambulatory BP control predicts cardiovascular risk better than office BP control in patients being treated for hypertension, although large-scale interventional trials are lacking.

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