AHA Medical/Scientific Statement

Special Report

Human Blood Pressure Determination by Sphygmomanometry

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This is the sixth edition of the American Heart Association's recommendations for indirect measurement of arterial blood pressure. The purpose is to facilitate the AHA's mission to reduce disability and death from cardiovascular diseases and stroke by providing practical guidelines for measuring an important physiological variable that contributes to and is associated with these major diseases. The recommendations are intended to provide a uniform standard and methodology for day-to-day use by all health care workers and for use in epidemiological, educational, and clinical studies. This edition clarifies and updates information provided in previous versions. The writing group is indebted to the previous groups and their chairs for their extensive work and expresses special appreciation to the late Dr. Walter Kirkendall for his lifelong work in the field of hypertension.

Arterial blood pressure, one of the "vital signs," is an important indicator of a person's state of health; therefore, its measurement is a part of every complete physical examination. Blood pressure measurement is done to screen for hypertension, to assess a person's suitability for certain occupations and activities, to estimate long-term cardiovascular risk, to determine eligibility for insurance, and as a part of the management of patients with many types of medical problems. Inappropriately low blood pressure, or clinical shock, is a medical emergency, and inappropriately high blood pressure is a marker for the chronic condition hypertension, which is a major risk factor for premature cardiovascular, cerebrovascular, renovascular, and other vascular diseases.

The gold standard for measurement of arterial pressure is direct intra-arterial measurement with a catheter. However, this technique is neither practical nor appropriate for repeated measurements in nonhospitalized patients or asymptomatic individuals, nor for largescale public health screenings. Instead, the indirect method of measurement is commonly used. With this technique the pressure required to collapse the artery in the upper arm or leg is determined by use of a sphygmomanometer (an occluding cuff, stethoscope, and manometer). The cuff is inflated to a level above arterial pressure (as indicated by obliteration of the pulse). As the cuff is gradually deflated, the pressure is noted at which sounds produced by the arterial pulse waves (Korotkoff sounds) appear and disappear again as flow through the artery resumes. The direct and indirect methods yield similar measurements, but these are rarely identical because the direct method measures pressure and the indirect method is more indicative of flow. The indirect method is generally less accurate and less reproducible. Nevertheless, it is sufficiently accurate for many diagnostic and therapeutic studies and will continue to be used because it is practical, simple, low in cost, and noninvasive.

Because the level of arterial pressure is the basis for major diagnostic and therapeutic decisions in medicine, the measurement must be correct and maximally reproducible. Although the occluding cuff technique appears simple and easy to learn, there are many possible causes of error and inaccuracy. Therefore, the technique for measurement should be standardized so that information from different observers is comparable and can be readily used in serial evaluations of an individual or for epidemiological and research studies. This report outlines a simple, standardized, step-by-step protocol for the indirect measurement of blood pressure. Routine, careful adherence to this protocol will facilitate accurate and reproducible (and reliable) quantification of this important physiological variable. This report is intended for everyone who measures blood pressure: health care workers, researchers, and people who measure their own blood pressure.

The scientific bases for these recommendations are provided when available; otherwise, consensus recommendations are made, in the interest of standardizing the procedure. The bibliography provides the sources of our recommendations and is a basis for further reading. The special considerations of measuring blood pressure in infants, children, the elderly, pregnant women, and the obese are reviewed. Because of the growing interest in self-measurement and ambulatory blood pressure measurement, these techniques and their applicability are also discussed. Appendix A is a list of potential errors in measuring blood pressure and ways to correct or avoid them. We emphasize the need for systematic training and recertification of observers and the desirability of regular recalibration of equipment. The importance of making accurate blood pressure measurements for the evaluation and treatment of hypertension.
are stressed in light of the epidemiological importance of this diagnosis.

**Epidemiology of Hypertension**

Hypertension is one of the major modifiable risk factors for stroke, coronary heart disease, congestive heart failure, renal failure, and peripheral vascular disease. It is estimated that 50 million Americans have a blood pressure level consistently at or above 140/90 mm Hg, and are therefore at increased risk for developing complications. The risk from hypertension is present whether only systolic pressure, only diastolic pressure, or both are elevated. Other potentially modifiable risk factors for cardiovascular, cerebrovascular, renovascular, and other vascular diseases include dyslipidemias, tobacco use, lack of exercise, diabetes mellitus, and excessive alcohol intake; the concurrent presence of multiple risk factors further increases the risk of developing cardiovascular disease. The diagnosis of hypertension consequently has serious implications for longevity and also affects insurability, employability, and suitability for certain occupations and activities. It is therefore imperative that the diagnosis of hypertension be based on accurate, representative, and reproducible measurements.

Hypertension is defined as a persistently elevated blood pressure; that is, a pressure that exceeds an arbitrarily set level of normality. Pressures above this level are associated with an escalating risk for the development of arteriosclerosis, left ventricular hypertrophy, nephrosclerosis, and cerebrovascular disease. Involvement of these target organs in turn leads to risk of decompensation of cardiac and renal function and of thrombotic, embolic, aneurysmal, or hemorrhagic vascular disease. The risk increases progressively: the higher the blood pressure and number of concurrent risk factors, the more advanced the degree of target organ involvement. Systolic and diastolic blood pressure are closely correlated and are correlated with risk of cardiovascular disease independently and in combination. However, high systolic pressure may contribute more to the risk of complications than high diastolic pressure. There is no blood pressure level below which there is no risk or above which cardiovascular complications are inevitable. The arbitrary division between “normal” and “abnormal,” despite the fact that risk increases in a continuum, is useful for classification of individual patients and for facilitation of both diagnostic and therapeutic decisions. Because the risk that an elevated pressure will lead to clinical sequelae is long term rather than short term, the diagnosis of hypertension should be based on multiple determinations over several visits. The Joint National Committee on the Diagnosis, Evaluation, and Treatment of Hypertension (JNC V) has recommended that in the nonhospitalized adult at least two measurements be made on two or more separate occasions, and only if the average of two readings is at or above 140/90 mm Hg should the individual be labeled as having hypertension (see Appendix B). A staged approach is, of course, unnecessary in the patient who has very high or rapidly rising blood pressure and is therefore at risk for developing acute cardiovascular complications.

Blood pressure levels normally fluctuate considerably from day to night or over longer periods of time. Blood pressure is influenced by level of activity, exercise or rest, degree of wakefulness or sleep, environmental factors such as temperature, mood (friendly or hostile), and a multitude of other emotional or psychological factors that reflect a person’s response to the internal and external milieu. No single blood pressure measurement reflects the entire day’s fluctuations. Yet blood pressure is frequently treated as a definitive, constant, physiological characteristic, and the individual numerical values are used as the basis for major diagnostic and therapeutic decisions, the most important of which is the diagnosis of hypertension. Therefore, to minimize the influence of extraneous factors on blood pressure variability, the use of a standardized protocol for measuring blood pressure is critical.

**Indirect Blood Pressure Measurement**

In 1896 Riva Rocci introduced a method for indirect measurement of blood pressure, based on measuring the external pressure required to compress the brachial artery so that arterial pulsations could no longer be transmitted through the artery. The artery is occluded by wrapping an inflatable bladder, which is encased in a nondistensible cuff, around an extremity, and inflating the bladder until the pressure in the cuff exceeds that in the artery. When the artery is occluded, transmitted pulse waves can no longer be palpated or heard distal to the point of occlusion. As the pressure in the bladder is reduced by opening a valve on the inflation bulb, pulsatile blood flow reappears through the partially compressed artery, producing repetitive sounds generated by the pulsatile flow. These “Korotkoff sounds” are named for the Russian physician who first described the auscultatory method in 1905. The level of the pressure in the inflatable bladder (reflected by the level on the manometer to which it is connected) at the appearance of the first Korotkoff sound is the maximum pressure generated during each cardiac cycle: the systolic pressure. The level of pressure at which the sounds disappear permanently, when the artery is no longer compressed and blood flow is completely restored, is the resting pressure between cardiac contractions: the diastolic pressure.

As the pressure is reduced during deflation of the occluding cuff, the Korotkoff sounds change in quality and intensity. The five phases of this change are characterized as follows:

Phase I: First appearance of clear, repetitive, tapping sounds. This coincides approximately with the reappearance of a palpable pulse.

Phase II: Sounds are softer and longer, with the quality of an intermittent murmur.

Phase III: Sounds again become crisper and louder.

Phase IV: Sounds are muffled, less distinct, and softer.

Phase V: Sounds disappear completely.

The pressure at which the sounds first appear (onset of Phase I) corresponds to the systolic pressure. There has been some debate, however, over whether the pressure at the onset of muffling (Phase IV) or disappearance of sound (Phase V) best corresponds with diastolic blood pressure. Generally, disappearance of sound correlates better with intra-arterial pressure than does muffling, and the pressures at which muffling and
disappearance occur often differ by only a few millimeters of mercury. Therefore, the onset of Phase V is used to define the diastolic pressure in adults. The onset of Phase V is defined by the level at which the last sound is heard or by the onset of silence, the level 2 mm Hg below that. Both definitions have been used in epidemiological studies, but the onset of silence, or absence of sound, is difficult to define or describe accurately, and the level of the last audible sound heard is easier to teach and to standardize. The consensus of the committee is therefore that, in the interest of uniformity, Phase V should be operationally defined by the last sound heard. In children less than 15 years old, pregnant women, and patients with high cardiac output or peripheral vasodilatation, sounds are often heard at levels far below those at which muffling occurs, sometimes to levels approaching 0 mm Hg. In these situations, for practical purposes, muffling should be used to indicate diastolic pressure, but both muffling (Phase IV) and disappearance (Phase V) should be recorded.

Occasionally the Korotkoff sounds become inaudible during Phase II or III, only to reappear as the pressure in the cuff is reduced further. This period of silence is called the auscultatory gap and is especially common in older and hypertensive patients. Pulsus alternans, or beat-to-beat variation in the intensity of the Korotkoff sounds, occurs in people with fluctuating systolic pressure. When the Korotkoff sounds first appear, while the arterial lumen is still partially compressed, only alternate ventricular contractions generate a systolic pressure sufficiently high to produce a pulse wave that results in audible sounds. As the pressure in the occluding cuff is reduced and the pressure in the inflatable bladder falls below the level generated by even the weaker systolic contractions, these too produce a pulse wave and the frequency of the Korotkoff sounds suddenly doubles. Pulsus paradoxus is an exaggeration of the normal fall in systolic pressure that occurs during inspiration. During inspiration, venous return to the right atrium and, therefore, right ventricular stroke volume increase, but venous return to the left atrium and left ventricular stroke volume decrease. This reduction of pressure is normally on the order of 2 to 4 mm Hg, and is considered abnormal when it exceeds 10 mm Hg. Pulsus paradoxus is commonly seen in patients with constrictive pericarditis or pericardial tamponade, but may also occur in patients with severe pulmonary disease and deep labored breathing or restrictive cardiomyopathy.

Procedure for Measuring Blood Pressure

The systematic step-by-step procedure for measuring blood pressure is described in this section. The errors that can occur at each stage, and suggestions for avoiding them, are summarized in Appendix A.

Equipment

The equipment for indirect measurement of blood pressure consists of a stethoscope, or sensing microphone for auscultation or detection of the Korotkoff sounds, and a sphygmomanometer. The sphygmomanometer comprises a manometer (mercury or aneroid), with a calibrated scale for measuring pressure, and an inflation system. The latter consists of an inflatable bladder encased in a nondistensible cuff that can be securely wrapped around the limb, an inflation bulb for manual inflation of the bladder in the cuff, and tubing connecting both the manometer and the inflation bulb to the bladder.

Stethoscope. The stethoscope, which consists of a microphone or head, tubing, and ear pieces, is placed over the occluded artery to amplify the Korotkoff sounds. The bell, or low-frequency filter of the microphone, permits more accurate auscultation of the Korotkoff sounds than the diaphragm, especially at diastolic pressures; its routine use is therefore recommended. However, the diaphragm is widely used because it is convenient, easily placed, and more generally available. Some of the sphygmomanometers designed for self-measurement of blood pressure are equipped with a microphone or sensor built into the occluding cuff. This obviates the inconvenience of holding the bell over the brachial pulse with one hand while compressing the bulb with the other hand, but may introduce extraneous sounds. The length of the tubing from the ear pieces to the microphone should be long enough that the seated observer can conveniently place the bell over the artery and listen for the sounds while observing the manometer at eye level (12 to 15 in, 30 to 38 cm).

Manometer. The calibrated manometer reflects the pressure in the occluding cuff by the height of a column of mercury or by the location of a rotating needle on a dial scale. The mercury manometer is preferred and recommended over the aneroid manometer because it is more accurate, easier to maintain, and less likely to become decalibrated. However, because of the risk of the toxic effects of mercury spills, mercury manometers must be handled carefully and their use has been discouraged in some areas of high traffic where accidental spills are more prone to occur. The column of mercury should have a height and calibration scale from 0 to 300 mm Hg, marked at intervals of 2 and 10 mm Hg. Smaller scales from 0 to 260 mm Hg are also available. The mercury reservoir should be full so that the upper curve of the manometer is at the zero level before the cuff is inflated. The mercury should rise and fall freely in the column; bouncing or hesitation of the mercury during deflation reflects clogging of the air vent or dirt or air bubbles in the column. The column should be kept vertical except on the specially designed floor models, which have a slanted scale. See Appendix C for safety precautions for the use of mercury.

The aneroid manometer is also widely used and can provide accurate measurements if properly calibrated. However, because of its construction, it is prone to mechanical alterations that can affect its accuracy. The aneroid manometer consists of a metal bellows, which expands as the pressure in the cuff increases, and a mechanical amplifier that transmits this expansion through a lever to the indicator needle, which rotates around a circular, calibrated scale. The needle should rest at the zero point before the cuff is inflated and return to that point after the cycle of inflation and deflation. Aneroid manometers require maintenance every 6 months and should be handled gently to avoid decalibration. The accuracy of the calibration should be checked regularly (Fig 1). Recalibration is required when the readings differ from the standard mercury manometer by more than 4 mm Hg. When decalibrated,
aneroid manometers tend to underread the pressure, especially at higher levels, but may be inconsistent in their variation from the mercury standard at any blood pressure level.

Inflation system. The inflation system consists of an expandable, rectangular rubber bladder encased in a nondistensible cuff, an inflation bulb, and connecting tubing. The cuffs used for oscillometric determination of the blood pressure do not have a removable bladder separate from the cuff. The cuff is applied by wrapping it completely around the limb so that the noninflatable portion overlaps that containing the bladder, and is secured with a self-adhesive material such as Velcro. The bladder is connected by rubber tubing to the manometer, which reflects the pressure inside the bladder. The tubing must be free of leaks and long enough that the subject can be comfortably positioned next to the manometer without the tube's becoming kinked or compressed, which could interfere with smooth inflation or deflation. The bladder is also connected by a shorter tube to a valved rubber bulb, which is used to inflate and deflate the bladder at a rate controlled by the release valve.

Considerable thought has been given to the size and dimensions of the occluding bladder and its encasing cuff.17-19 The variables considered are the length and width of the bladder and the ratio of one to the other, the relation of the width of the bladder to the length of the upper arm, and the relation of both the width and the length of the bladder to the circumference of the arm. For any arm circumference, as the bladder size (length and width) is increased in a stepwise manner the blood pressure reading is progressively lower, until a plateau is reached at which no further increase in cuff size results in further reduction of the blood pressure measurement.19 This plateau occurs approximately when the width of the bladder is 40% of the circumference of the upper arm at the midpoint and the length of the bladder is 80% of the circumference of the arm. The use of a bladder that is too small (too narrow or too short) for the circumference of the limb results in overestimation of the blood pressure.19 The error of underestimation of the pressure, which results from the use of a bladder that is too large, is less than the error of overestimation with a bladder that is too small. To date there is no published systematic study that relates the measurements made with stepwise increments in cuff dimensions (length and width), in arms of varying circumferences and lengths, to simultaneous intra-arterial measurements. Hence, the committee's consensus recommendation is based on the available literature. It is recommended that the width of the bladder be 40% of the arm circumference, and the length of the bladder be long enough to encircle at least 80% of the arm in adults. In children the occluding bladder should be long enough to encircle the arm completely (100%). Overlapping of the ends of the bladder in children does not appear to introduce an error in measurement.

The cuffs generally available have been classified by the width of the bladder rather than by the length, and are labeled "newborn," "infant," "child," "small adult," "adult," "large adult," and "thigh," but different manufacturers have produced cuffs of varying dimensions (both length and width) under these names because no universal standards have been established. A large number of cuffs with varying sizes of bladders are commercially available, but not all of these are of the recommended dimensions. Ideally, every cuff should be labeled with the dimensions of the enclosed bladder; a line should mark the center of the bladder, and two lines should indicate the range of arm circumferences for which the bladder is suitable, ie, encircling 80% to 100% of the circumference (Fig 2). Unlabeled cuffs should be so marked by the user. For cuffs with longer bladders, a length:width ratio of more than 2:1, the corresponding appropriate arm circumference is greater; however, the ratio of bladder width to arm circumference should be as close as possible to 0.40. (See Appendix D for a list of some acceptable bladder sizes and the arm circumferences for which they are suitable. A number of cuffs with intermediate bladder dimensions are available, but to simplify the selection only some of them are listed here.) Although it is not feasible for every examiner to have all cuff sizes available, except under research conditions, it is strongly
recommended that the practitioner have several sizes available to meet the needs of the population served. However, in individuals with very wide but short arms, the appropriately sized bladder may be difficult to apply. Likewise, in individuals with very large or muscular arms, even the largest cuff may be inadequate. The British Hypertension Society has recommended the use of one large cuff (12.5 × 35 cm) for all adults with an arm circumference up to 42 cm, to avoid the need for multiple cuff sizes. The use of such a cuff could lead to systematic underestimation or overestimation of the pressure when the ratio of bladder width to arm circumference is different from 0.40.

Automated devices. Many automated devices are available to measure blood pressure by both auscultatory and oscillometric techniques. The oscillometric method is based on detecting the oscillations on the lateral walls of the occluded artery as the cuff is deflated. The oscillations begin at approximately the level of systolic pressure and reach their greatest amplitude at the level of mean arterial pressure. Diatolic pressure is a derived value. Systolic blood pressure measurement by these devices is accurate, but diastolic pressure, which is derived from the systolic and mean pressures, may not be. The cuffs used for oscillometric measurement are constructed without a removable bladder. Although absolute measurements made with these cuffs may vary slightly from those made with standard cuffs, overall trends in blood pressure level can be readily tracked. However, serious doubt has been raised about the accuracy of devices applied to the finger or wrist because their extreme sensitivity to position results in wide fluctuations in blood pressure readings except when they are used under strictly standardized and constant conditions; hence, their use is not recommended. Doppler devices, which amplify the Doppler signal from flowing blood, are also used with standard sphygmomanometers and obviate the need for a stethoscope. They are especially useful in taking infants' blood pressure or in situations where the auscultatory signal is difficult to hear.

Observer

Every person who makes indirect blood pressure measurements must be carefully trained and made aware of the potential pitfalls. Several excellent programs, some using videocassettes, provide standardized instruction, training, and testing of observers. Unfortunately, many health care professionals do not participate in regular retraining programs to improve and reassess their skills in blood pressure measurement, despite considerable variability in their knowledge, skill, and technique. The observer must be able to concentrate on the task and have reasonably good eyesight, hearing, and manual dexterity as well as hand-eye coordination. The observer must be comfortably positioned to be able to (1) inflate and deflate the bladder in the cuff gradually, (2) see the manometer and the meniscus of the column of mercury or the indicator needle on the aneroid scale, (3) hear the Korotkoff sounds, differentiating them from extraneous noises, (4) make note of and remember the level of the pressure at the first appearance, at muffling, and at the disappearance of the Korotkoff sounds, while continuing to deflate the occluding cuff, and (5) remember and record the systolic and diastolic pressure (Phases IV and V) accurately to the nearest 2 mm Hg.

Observer errors can also result from subconscious biases. Terminal digit preference is caused by the tendency to round pressure readings off to numbers ending in zero instead of recording more accurately to the nearest 2 mm Hg. A cut-off or direction bias results in falsely recording pressures as being above or below a predetermined level or dividing line between "normal" and "hypertensive." An observer may also be influenced by knowledge of earlier readings.

Subject

For screening and monitoring purposes, the blood pressure is measured in the upper arm, with the subject seated. Serial measurements should be performed on the same arm for consistency. Under clinical circumstances, measurements are often performed in other positions as well. In the initial evaluation of hypertensive patients, the blood pressure should be measured in both arms and occasionally in the legs. The subject must be comfortably seated with the midpoint of the upper arm at the level of the heart (approximately the fourth intercostal space, when the individual is seated). When the subject is standing, care must be taken to support the raised arm at the level of the heart. When the subject is lying down, the arm should be at the side of the body, slightly raised from the bed or examination table, at the level of the middle of the chest. Ideally the measurements should be made after a fraction of rest in a quiet, relaxed setting, not immediately after exertion or ingestion of coffee or during conversation; the legs should be uncrossed, with the feet resting firmly on the floor, not dangling, and the back supported, because any form of isometric exercise during the measurement will transiently raise the blood pressure level. Blood pressure levels are affected by environmental, emotional, and physical stimuli, so every effort should be made to standardize the conditions of the measurement, keeping extraneous influences to a minimum. Anticipation of pain or anxiety about the procedure and its outcome can raise the blood pressure level and potentially lead to overestimation of the usual blood pressure levels.

Technique

The intent and purpose of the measurement should be explained to the subject in a reassuring manner and every effort made to put the subject at ease.

The sequential steps for measuring the blood pressure in the upper extremity, as for routine screening and monitoring purposes, should include the following:

1. Have paper and pen at hand for immediate recording of the pressure.
2. Seat the subject in a quiet, calm environment with his or her bare arm resting on a standard table or other support so the midpoint of the upper arm is at the level of the heart.
3. Estimate by inspection or measure with a tape the circumference of the bare upper arm at the midpoint between the acromion and olecranon process (between the shoulder and elbow) and select an appropriately sized cuff. The bladder inside the cuff should encircle 80% of the arm in adults and 100% of the arm in children less than 13 years old. If in doubt, use a larger...
cuff. If the available cuff is too small, this should be noted.

4. Palpate the brachial artery and place the cuff so that the midline of the bladder is over the arterial pulsation, then wrap and secure the cuff snugly around the subject’s bare upper arm. Avoid rolling up the sleeve in such a manner that it forms a tight tourniquet around the upper arm. Loose application of the cuff results in overestimation of the pressure. The lower edge of the cuff should be 1 in (2 cm) above the antecubital fossa (bend of the elbow), where the head of the stethoscope is to be placed.

5. Place the manometer so the center of the mercury column or aneroid dial is at eye level and easily visible to the observer and the tubing from the cuff is unobstructed.

6. Inflate the cuff rapidly to 70 mm Hg, and increase by 10 mm Hg increments while palpating the radial pulse. Note the level of pressure at which the pulse disappears and subsequently reappears during deflation. This procedure, the palpatory method, provides a necessary preliminary approximation of the systolic blood pressure to ensure an adequate level of inflation when the actual, auscultatory measurement is made. The palpatory method is particularly useful to avoid underinflation of the cuff in patients with an auscultatory gap and overinflation in those with very low blood pressure.

7. Place the earpieces of the stethoscope into the ear canals, angled forward to fit snugly. Switch the stethoscope head to the low-frequency position (bell). The setting can be confirmed by listening as the stethoscope head is tapped gently.

8. Place the head of the stethoscope over the brachial artery pulsation, just above and medial to the antecubital fossa but below the lower edge of the cuff, and hold it firmly in place, making sure that the head makes contact with the skin around its entire circumference. Wedging the head of the stethoscope under the edge of the cuff may free up one hand but results in considerable extraneous noise.

9. Inflate the bladder rapidly and steadily to a pressure 20 to 30 mm Hg above the level previously determined by palpation, then partially unscrew (open) the valve and deflate the bladder at 2 mm/sec while listening for the appearance of the Korotkoff sounds.

10. As the pressure in the bladder falls, note the level of the pressure on the manometer at the first appearance of repetitive sounds (Phase I) and at the muffling of these sounds (Phase IV) and when they disappear (Phase V). During the period the Korotkoff sounds are audible, the rate of deflation should be no more than 2 mm per pulse beat, thereby compensating for both rapid and slow heart rates.

11. After the last Korotkoff sound is heard, the cuff should be deflated slowly for at least another 10 mm Hg, to ensure that no further sounds are audible, and then rapidly and completely deflated, and the subject should be allowed to rest for at least 30 seconds.

12. The systolic (Phase I) and diastolic (Phase V) pressures should be immediately recorded, rounded off (upwards) to the nearest 2 mm Hg. In children, and when sounds are heard nearly to a level of 0 mm Hg, the Phase IV pressure should also be recorded. All values should be recorded together with the name of the subject, the date and time of the measurement, the arm on which the measurement was made, the subject’s position, and the cuff size (when a nonstandard size is used).

13. The measurement should be repeated after at least 30 seconds, and the two readings averaged. In clinical situations additional measurements can be made in the same or opposite arm, in the same or an alternative position. Systematic errors that observers often make are listed in Appendix A, as are suggestions for improving the technique.

### Blood Pressure Recording in Special Situations

#### Infants and Children

Measuring blood pressure in infants and children presents special problems because of their frequent lack of cooperation, although the same techniques are used as in adults. Several pediatric cuff sizes are available and should be selected as indicated (see Appendix D) to ensure that the bladder completely encircles the limb. Because the Korotkoff sounds are often heard through the entire period of deflation, determining diastolic pressure as Phase IV is recommended in children less than 13 years old. (See “Report of the Second Task Force on Blood Pressure Control in Children.”) In small children and infants, the palpatory method is often used for approximating systolic pressure, even though this may be 5 to 10 mm Hg lower than the level measured by auscultation. In very small infants, the blood pressure is often determined by the flush method, which involves placing a suitable cuff on the arm or leg, raising the limb, and wrapping the extremity distal to the cuff firmly with an elastic bandage until it is drained of blood and blanches. The limb is then lowered to heart level, the cuff is rapidly inflated, and the bandage is removed. As the pressure in the cuff is gradually reduced, flushing of the limb indicates the level at which flow returns. This level corresponds to mean blood pressure but is inaccurate in infants with anemia, hypothermia, or edema. The technique is rarely used now; newer automated oscillometric or Doppler equipment can be used instead.

#### Elderly Patients

In elderly patients who have sclerotic, calcified vessels, it is likely that the systolic pressure is overestimated by the indirect method of measurement. A readily palpable brachial artery that can be felt even when the cuff has been inflated and the blood flow is interrupted (positive Osler’s sign) provides a clue that the measurement may be inaccurate. Under such circumstances, an erroneous diagnosis of hypertension, or “pseudohypertension,” may be made, although this can only be confirmed by direct measurement. Because postural hypotension is often observed in elderly patients, blood pressure measurement should routinely be made in both the sitting and standing positions, especially in patients who are labeled hypertensive or who are receiving antihypertensive therapy. Because of the tendency for blood pressure to be more labile in elderly patients, it is particularly important to obtain several baseline determinations before making diagnostic or therapeutic decisions.
Pregnant Patients

In pregnant women, a rise in blood pressure or the diagnosis of hypertension has major significance for the outcome of the pregnancy for both the mother and the fetus. Measuring the blood pressure of pregnant women is more complicated because of the wide pulse pressure and the need to record both Phase IV and Phase V because sounds can often be heard to 0 mm Hg. In the third trimester, especially, the mother's position can affect blood pressure levels; measurements made with the woman in the left lateral decubitus position, with the arm below the level of the heart, are often lower than those made in the sitting position with the arm at heart level.33

Obese Patients

A longer and wider cuff is needed for adequate compression of the brachial artery in the obese patient with a very large upper arm.18,19,34,35 A large cuff may also be required for a big, muscular arm with a prominent biceps over which a regular, nontapered cuff might not fit smoothly. In both situations it is particularly important to place the center of the bladder over the brachial artery pulse. If the upper arm is relatively short despite the large circumference, it may be difficult to fit a standard large adult cuff over the arm. The British Hypertension Society's recommendation to use a very long cuff (12.5 x 35 cm) could obviate this problem. In the rare patient with an arm circumference greater than 50 cm, when even a thigh cuff cannot be fitted over the arm, it is recommended that the health care practitioner wrap the cuff around the patient's forearm and feel for the appearance of the radial pulse at the wrist. The accuracy of this method has not been validated, but it provides at least a general estimate of the systolic blood pressure. The error of overestimating the pressure when measuring with a cuff that is too small for an obese arm can be considerable and can lead to misclassification of an individual as hypertensive and to unnecessary concern and therapy.

Miscellaneous Conditions

In patients who are clinically in shock it may be difficult to hear the Korotkoff sounds or palpate a peripheral pulse because of generalized vasocostriction. Indirect blood pressure measurements can be very unreliable in this situation. An approximate estimate of the systolic pressure can be made using the palpatory method. The direct method, using an intra-arterial line, is preferable under these circumstances.

In patients who have a high cardiac output (eg, thyrotoxic or febrile patients or patients with aortic valve insufficiency, an arteriovenous fistula, or peripheral vasodilatation) and in children, the Korotkoff sounds can often be heard to a level close to 0 mm Hg. In such patients the pressure at which Phase IV (muffling) occurs should be used as an approximate index of diastolic pressure, but both Phase IV and Phase V pressures should be recorded.

In patients who have recently undergone a mastectomy with extensive axillary node dissection or other surgical procedure involving the arm or shoulder, it is recommended that blood pressure be measured in the opposite arm. Likewise, in dialysis patients, measuring blood pressure in the arm with the arteriovenous fistula should be avoided.

In patients with cardiac dysrhythmias such as atrial fibrillation or frequent premature beats, the systolic pressure may vary widely from beat to beat, so the pressures at which the first and last Korotkoff sounds are heard may differ from measurement to measurement. In such situations the rate of deflation should be more gradual and multiple blood pressure determinations should be made and averaged. In patients with a slow heart rate, it is particularly important to reduce the pressure in the cuff gradually (2 mm Hg per heart beat) to avoid underestimation of systolic pressure and overestimation of diastolic pressure.

Disparity in pressure between the two arms may occur in patients with congenital heart disease, peripheral vascular disease, unilateral neurological and musculoskeletal abnormalities, and aortic dissection. Although the blood pressure should routinely be measured in both arms on the initial examination of a hypertensive patient, under the above circumstances this recommendation is of particular importance. A consistent difference should be noted, and in hypertensive patients the arm with the higher pressure should be used for subsequent measurements. In patients with stenosis of the subclavian, axillary, or brachial artery, the presence of a bruit may interfere with interpretation of the Korotkoff sounds.

An auscultatory gap, often detected in patients with high systolic pressure, is not abnormal.13,36 However, if the systolic pressure is not first estimated by palpation, insufficient inflation of the cuff can lead to erroneous designation of the lower end of the gap as the systolic pressure.

Measurements made during exercise, as during a treadmill test, are difficult to make and often inaccurate when made with currently available equipment. The use of oscillometric or Doppler equipment may provide a more accurate measurement in these situations.

Measuring blood pressure in the lower extremity is indicated in subjects who are suspected of having coarctation of the aorta or other types of obstructive aortic disease. The thigh cuff is used in adults and a large cuff in infants and children. With the subject lying face down, the cuff is applied with the center of the inflatable bladder over the posterior aspect of the midthigh. The head of the stethoscope is placed over the artery in the popliteal fossa (behind the knee) and the Korotkoff sounds are monitored as the pressure in the bladder is lowered, in the same manner as in the arms. If the subject is unable to lie face down, thigh pressures can be taken with the subject lying on the side or back, with the knee slightly flexed so the stethoscope can be placed over the popliteal pulse easily. The diastolic pressure in the legs is usually similar to that in the arms, while the systolic pressure may be 20 to 30 mm Hg higher. Systolic pressure can be approximated in the lower leg by palpating the posterior tibial or dorsalis pedis pulses while inflating and deflating the cuff applied to the calf, with the lower end of the cuff above the malleolus.

Self-Measurement or Home Measurement of Blood Pressure

Self-measurement of blood pressure, usually at home, has become popular, especially among hypertensive individuals.37 Self-measurement facilitates patients' par-
Ambulatory changes need for frequent coat” informs titration participation been been. Several automatic oscillometric assessing sure and manual inflation measurement trained and merit made on detection of Korotkoff sounds, and others use the oscillometric technique. The newer machines are easier to use than the mercury manometer and stethoscope but require periodic recalibration.

Ambulatory Blood Pressure Measurements

Ambulatory blood pressure measurements refers to repeated measurements made away from the medical environment with a portable, automatic (self-inflating) recorder in patients engaging in their usual activities. These measurements are particularly useful in patients in whom there is a wide disparity between physician- and self-determined pressures, making it difficult to know which blood pressure level to use for diagnostic and therapeutic decisions. Ambulatory measurements are also useful for relating fluctuations in blood pressure level to symptoms reported by the patient and for assessing the effect of antihypertensive therapy. A number of miniature, lightweight, silent, fully automatic machines are now available, but continued validation of their accuracy, calibration, and conformity with standards is urged.

In most, but not all, hypertensive patients the blood pressure obtained in a physician’s office is higher than the pressures measured during the remainder of the day. If the office pressures are in the range defined as hypertensive, and the pressures during the remainder of the day are in the “normal” range, the patient is said to have “white-coat hypertension.”42 Patients who respond to the physician’s examination with an exaggerated rise in blood pressure tend to have a lesser pressor response to an encounter with a nurse and may have lower or even normal blood pressures at other times, as determined by automatic ambulatory blood pressure monitoring.43 Patients who have white-coat hypertension may be at risk for being diagnosed as having persistent hypertension and for being overtreated. However, because all existing epidemiological studies of hypertension are based on office blood pressure measurements, further longitudinal research is needed to clarify the role of ambulatory blood pressure monitoring in the management of patients with raised arterial pressure.

Conclusion

The above recommendations for the technique of measuring blood pressure represent the consensus of the committee and are based on currently available information and the work of previous committees. The recommendations are subject to further revision as better validation data become available. The intent at this time is to provide, in the interest of uniformity and consistency, a standardized technique for measuring blood pressure.
### APPENDIX A

#### Common Problems in Measuring Blood Pressure and Recommendations for Avoiding Them

<table>
<thead>
<tr>
<th>Problem</th>
<th>Result</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stethoscope ear pieces plugged</td>
<td>Poor sound transmission</td>
<td>Clean ear pieces</td>
</tr>
<tr>
<td>Ear pieces poorly fitting</td>
<td>Distorted sounds</td>
<td>Angle ear pieces forward</td>
</tr>
<tr>
<td>Bell or diaphragm cracked</td>
<td>Distorted sounds</td>
<td>Replace equipment</td>
</tr>
<tr>
<td>Tubing too long</td>
<td>Distorted sounds</td>
<td>Length from ear pieces to bell should be 12 to 15 in (30 to 38 cm)</td>
</tr>
<tr>
<td>Mercury manometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meniscus not at 0 at rest</td>
<td>Inaccurate reading</td>
<td>Replace or remove mercury</td>
</tr>
<tr>
<td>Column not vertical</td>
<td>Inaccurate reading</td>
<td>Place manometer on level surface</td>
</tr>
<tr>
<td>Bouncing of mercury with inflation/deflation</td>
<td>Inaccurate reading</td>
<td>Clean tubing and air vent, replace mercury</td>
</tr>
<tr>
<td>Aneroid manometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Needle not at 0 at rest</td>
<td>Inaccurate reading</td>
<td>Recalibrate</td>
</tr>
<tr>
<td><strong>Observer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit preference</td>
<td>Inaccurate reading</td>
<td>Be aware of tendency; record blood pressure to nearest 2 mm Hg</td>
</tr>
<tr>
<td>Cut-off bias</td>
<td>Inaccurate reading</td>
<td>Record to nearest 2 mm Hg</td>
</tr>
<tr>
<td>Direction bias</td>
<td>Inaccurate reading</td>
<td>Record to nearest 2 mm Hg</td>
</tr>
<tr>
<td>Fatigue or poor memory</td>
<td>Inaccurate reading</td>
<td>Write down reading immediately</td>
</tr>
<tr>
<td><strong>Subject</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm below heart level</td>
<td>Reading too high</td>
<td>Place patient with midpoint of upper arm at heart level</td>
</tr>
<tr>
<td>Arm above heart level</td>
<td>Reading too low</td>
<td>Place patient with midpoint of upper arm at heart level</td>
</tr>
<tr>
<td>Back unsupported</td>
<td>Blood pressure too high</td>
<td>Avoid isometric exercise during measurement</td>
</tr>
<tr>
<td>Legs dangling</td>
<td>Blood pressure too high</td>
<td>Avoid isometric exercise during measurement</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>Blood pressure level variable</td>
<td>Make multiple measurements and average</td>
</tr>
<tr>
<td>Large or muscular arm</td>
<td>Blood pressure reading high</td>
<td>Use appropriate cuff size</td>
</tr>
<tr>
<td>Calciﬁed arteries</td>
<td>Blood pressure reading high</td>
<td>Note presence of positive Osler sign in record</td>
</tr>
<tr>
<td><strong>Technique</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrapped too loosely</td>
<td>Blood pressure reading too high</td>
<td>Rewrap more snugly</td>
</tr>
<tr>
<td>Applied over clothing</td>
<td>Inaccurate reading</td>
<td>Remove arm from sleeve</td>
</tr>
<tr>
<td><strong>Manometer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below eye level</td>
<td>Blood pressure reading too low</td>
<td>Place manometer at eye level</td>
</tr>
<tr>
<td>Above eye level</td>
<td>Blood pressure reading too high</td>
<td>Place manometer at eye level</td>
</tr>
<tr>
<td><strong>Stethoscope head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not in contact with skin</td>
<td>Extraneous noise</td>
<td>Place head correctly</td>
</tr>
<tr>
<td>Applied too ﬁrmly</td>
<td>Diastolic reading too low</td>
<td>Place head correctly</td>
</tr>
<tr>
<td>Not over artery</td>
<td>Sounds not well heard</td>
<td>Place head over palpated artery</td>
</tr>
<tr>
<td>Touching tubing or cuff</td>
<td>Extraneous noise</td>
<td>Place below edge of cuff</td>
</tr>
<tr>
<td>Palpatory pressure omitted</td>
<td>Danger of missing auscultatory gap</td>
<td>Routinely check systolic pressure by palpation first</td>
</tr>
<tr>
<td>Underestimation of systolic pressure</td>
<td>Patient discomfort</td>
<td>Inflate to 30 mm Hg above palpatory blood pressure</td>
</tr>
<tr>
<td><strong>Inﬂation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inﬂation level too high</td>
<td>Underestimation of systolic pressure</td>
<td>Inflate to 30 mm Hg above palpatory blood pressure</td>
</tr>
<tr>
<td>Inﬂation level too low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inﬂation rate too slow</td>
<td>Patient discomfort</td>
<td>Inflate at even rate</td>
</tr>
<tr>
<td>Deflation rate too fast</td>
<td>Diastolic pressure too high</td>
<td>Deflate at 2 mm Hg/s or 2 mm Hg per beat</td>
</tr>
<tr>
<td>Deflation rate too slow</td>
<td>Systolic pressure too low</td>
<td>Deflate at 2 mm Hg/s or 2 mm Hg per beat</td>
</tr>
<tr>
<td>Forearm congestion</td>
<td>Diastolic pressure too high</td>
<td>Completely deflate cuff at end of measurement</td>
</tr>
</tbody>
</table>

In patients in whom the Korotkoff sounds are faint and difﬁcult to hear, the following technique may help: Have the subject raise the arm over the head and make a fist several times. Inflate the cuff, while the arm is still overhead but the hand relaxed, to a level 50 mm Hg above expected systolic level, have the patient lower the arm rapidly, and measure the blood pressure in the usual manner. Draining the venous blood in this fashion often ampliﬁes the Korotkoff sounds and makes weak sounds, particularly diastolic sounds, more audible.
**APPENDIX B**

Recommendations of the Joint National Committee on the Diagnosis, Evaluation, and Treatment of Hypertension for Classifying and Defining Blood Pressure Levels for Adults (Aged 18 Years and Older)*

<table>
<thead>
<tr>
<th>Category</th>
<th>Systolic (mm Hg)</th>
<th>Diastolic (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;130</td>
<td>&lt;85</td>
</tr>
<tr>
<td>High normal</td>
<td>130-139</td>
<td>85-89</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1 (mild)</td>
<td>140-159</td>
<td>90-99</td>
</tr>
<tr>
<td>Stage 2 (moderate)</td>
<td>160-179</td>
<td>100-109</td>
</tr>
<tr>
<td>Stage 3 (severe)</td>
<td>180-209</td>
<td>110-119</td>
</tr>
<tr>
<td>Stage 4 (very severe)</td>
<td>≥210</td>
<td>≥120</td>
</tr>
</tbody>
</table>

*Not taking antihypertensive drugs and not acutely ill. When systolic and diastolic pressures fall into different categories, the higher category should be selected to classify the individual's blood pressure status. For instance, 160/92 mm Hg should be classified as Stage 2, and 180/120 mm Hg should be classified as Stage 4. Isolated systolic hypertension is defined as systolic blood pressure ≥140 mm Hg and diastolic blood pressure <90 mm Hg and staged appropriately (eg, 170/85 mm Hg is defined as Stage 2 isolated systolic hypertension).

†Optimal blood pressure with respect to cardiovascular risk is systolic blood pressure <120 mm Hg and diastolic blood pressure <80 mm Hg. However, unusually low readings should be evaluated for clinical significance.

‡Based on the average of two or more readings taken at each of two or more visits following an initial screening.

In addition to classifying stages of hypertension based on average blood pressure levels, the clinician should specify presence or absence of target-organ disease and additional risk factors. For example, a patient with diabetes and a blood pressure of 142/94 mm Hg plus left ventricular hypertrophy should be classified as "Stage 1 hypertension with target-organ disease (left ventricular hypertrophy) and with another major risk factor (diabetes)." This specificity is important for risk classification and management.

From Reference 2.

**APPENDIX C**

Precautions Against Contamination With Mercury

Metallic mercury is an element that is liquid at room temperature and tends to break into tiny, highly mobile droplets when spilled. These droplets vaporize and can contaminate the atmosphere. In laboratories, offices, and clinics where mercury manometers are used regularly, precautions must be taken to limit the inhalation, ingestion, or absorption of mercury by personnel in case of a spill or breakage. It is recommended that health care personnel refer corrective mercury manometers for servicing by professionals. In the event of a mercury spill, the room should be well ventilated and the spilled mercury carefully swept up, not vacuumed, and taken to the laboratory for disposal. Personnel involved with the regular use of mercury manometers should be familiar with the available institutional facilities for handling mercury spills.

**APPENDIX D**

Acceptable Bladder Dimensions (in cm) for Arms of Different Sizes*

<table>
<thead>
<tr>
<th>Cuff</th>
<th>Bladder Width (cm)</th>
<th>Bladder Length (cm)</th>
<th>Arm Circumference Range at Midpoint (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>3</td>
<td>6</td>
<td>≤6</td>
</tr>
<tr>
<td>Infant</td>
<td>5</td>
<td>15</td>
<td>6-15†</td>
</tr>
<tr>
<td>Child</td>
<td>8</td>
<td>21</td>
<td>16-21†</td>
</tr>
<tr>
<td>Small adult</td>
<td>10</td>
<td>24</td>
<td>22-26</td>
</tr>
<tr>
<td>Adult</td>
<td>13</td>
<td>30</td>
<td>27-34</td>
</tr>
<tr>
<td>Large adult</td>
<td>16</td>
<td>38</td>
<td>35-44</td>
</tr>
<tr>
<td>Adult thigh</td>
<td>20</td>
<td>42</td>
<td>45-52</td>
</tr>
</tbody>
</table>

*There is some overlapping of the recommended range for arm circumferences in order to limit the number of cuffs; it is recommended that the larger cuff be used when available.

†To approximate the bladder width:arm circumference ratio of 0.40 more closely in infants and children, additional cuffs are available.


Human blood pressure determination by sphygmomanometry.
D Perloff, C Grim, J Flack, E D Frohlich, M Hill, M McDonald and B Z Morgenstern

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