Recommendations for Human Blood Pressure Determinations by Sphygmomanometers

By James Bordley, III, M.D., Charles A. R. Connor, M.D., W. F. Hamilton, M.D., William J. Kerr, M.D., and Carl J. Wiggers, M.D.

It should be clearly recognized that arterial pressures cannot be measured with precision by means of sphygmomanometers. Direct registration of pressures by calibrated intra-arterial manometers has shown (1) that even during quiet breathing and slight sinus arrhythmia, systolic and diastolic pressures vary from beat to beat by several mm. Hg, and that these differences are greatly intensified during states of arrhythmia and deep breathing; (2) that auscultatory systolic readings from the brachial artery average 3 or 4 mm. Hg too low and show average scatter of ±8 mm. Hg; and (3) that auscultatory diastolic pressures taken at the point of dulling of the sounds average about 8 mm. Hg too high. The errors of clinical measurement of blood pressure can be summarized by saying that in normal persons a mean error of ±8 mm. Hg may be expected in individual readings of systolic and diastolic pressures. Despite this, clinical blood pressure determinations have proved very serviceable for practicing physicians, clinicians, insurance carriers, and others concerned with physical examinations, diagnosis, prognosis, or therapy. It is important, however, that any basic deficiency of sphygmomanometry be not increased by additional errors due to apparatus or technic.

The following recommendations have been drawn up with the idea of aiding examiners to avoid pitfalls and, as far as possible, to establish greater reliability and uniformity in measuring systolic and diastolic pressures.

Apparatus

A sphygmomanometer consists of (1) a compression bag surrounded by an unyielding cuff for application of an extra-arterial pressure, (2) a manometer by which the applied pressure is read, (3) an inflating bulb, pump, or other device by which pressure is created in the system, and (4) a variable, controllable exhaust by which the system can be deflated either gradually or rapidly.

In the selection and maintenance of an instrument attention must be given to accuracy of construction and performance.

I. Mercurial types of manometers should be provided with a device to prevent spilling of the mercury when not in use. The zero level of the mercury should be easy to check and the scale should accurately indicate differences between the levels of mercury in the tube and the reservoir. Construction of the manometer should be such that the tubes and mercury can be cleaned without too much difficulty.

II. In the case of aneroid manometers, the readings on the dial at different pressures should check with those of a properly constructed and perfectly functioning mercury manometer. The fact that the pointer indicates zero may be no guarantee of accuracy over the whole pressure range. When placed and held under pressure for some time the pointer should not shift or creep.

III. The inflatable bag should, roughly speaking, be 20 per cent wider than the diameter of the arm or thigh on which it is to be used. Bags having the following widths are commercially available: for thighs of adults, 18 cm. (appendix VI); for arms of adults, 12 cm.; for children under 8 years, 8 or 9 cm.; under 4 years, 5 or 6 cm.; under one year, 2.5 cm. or less. A length of bag sufficient to half-encircle

The authors constituted the Committee to Revise "Standardization of High Blood Pressure Readings." This Committee, whose Chairman was Dr. Carl J. Wiggers, functioned under the auspices of the Council for High Blood Pressure Research of the Scientific Council of the American Heart Association.

These recommendations are being presented simultaneously in Circulation and in the Journal of the American Medical Association.
a limb is adequate provided care is taken by
the operator to place it on the side of the
compressible artery. However, some authorities
believe that any risk of misapplication should
be obviated by use of a bag that nearly or
completely encircles a limb.

The bag should be covered by a cuff of in-
extendible material of such a nature that an
even pressure is exerted throughout the width
of the cuff which lies over the artery. The cuff
should have a convenient device for securely
fastening after it has been applied to a limb.
The cuff and its locking mechanism should be
so constructed that inflation of the bag causes
neither bulging nor displacement. There is no
good evidence that any of several fastening
deVICES featured by different manufacturers en-
harases the accuracy of pressure readings.
Choice depends on personal ideas of conveni-
ence and manufacturers are to be commended
on their improvement on the old fastening by
a tapered cloth.

IV. Instruments in use should be checked
frequently for significant leaks in pressure
tubing and the compression bag, and com-
petent, smooth functioning of the bulb exhaust
and valves. Mercury manometers should be
inspected often for loss of mercury, which leads
to displacement of zero levels, and for dirty
tubes and oxidation of mercury, which causes
formation of a poor meniscus and clogging of
air vents at the top of manometer tubes. Old
leather filter discs should be replaced with ones
of proper porosity as supplied by manufac-
turers.

TECHNIC

I. The Patient. The patient may be either in
a recumbent position or comfortably seated.
The patient should be placed at ease and time
should be allowed for recovery from any un-
usual recent exercise, meals, or apprehension.
The arm should be bared, slightly flexed, ab-
ducted, and perfectly relaxed. In the sitting
position the forearm should be supported at
heart level on a smooth surface. The hand may
be pronated or supinated later, depending on
which position is found to yield the clearest
sounds. The deflated bag and cuff should be
applied evenly and snugly around the arm with
the lower edge about 1 inch above the ante-
cubital space. If the veins of the forearm are
prominently filled or there is evidence of con-
gestion the cuff should be applied while the arm
is elevated in order to promote venous drainage.

II. General Precautions. The mercury col-
umn must be vertical. The meniscus should
be read at a level with the observer's eye. It
is not important to place the manometer at
the heart level. The sounds heard on ausculta-
tion are not heart sounds; some misconception
regarding this still exists.

III. Determination of Systolic Pressure by the
Palpatory Method. A comparison of systolic
pressure by the palpatory and auscultatory
method is always advisable except in infants
in which the former method alone may be
feasible. Since it is impossible for an individual
to make simultaneous readings by the two
methods unless a bracelet form of stethoscope
receiver is used, a preliminary determination
of systolic pressure by the palpatory method
is advantageous. Such observations reassure
the patient and offer the examiner a rough idea
as to the maximum pressure to which the
system needs to be elevated in subsequent
determinations.

The patient's radial pulse should be palpated
and its rate and regularity estimated and re-
corded. The pressure of the system should be
raised to a level about 30 mm. Hg over the
point at which the radial pulse disappears.
Pressure should then be released slowly from
the system at such a rate that pressure in the
manometer falls about 2 to 3 mm. Hg per heart
beat. (See appendix I.) The return of palpable
beats at the normal rate of the heart should be
noted as a preliminary estimate of systolic
pressure. The cuff should be rapidly and com-
pletely deflated before further determinations
are made. The whole procedure should be car-
rried out as quickly as is consistent with ac-
curate determinations.

IV. Determination of Systolic Pressure by the
Auscultatory Method. A stethoscope receiver
should be applied snugly over the artery in the
ante-cubital space, free from contact with the
cuff. (See appendix II.A.) The pressure in the
sphygmomanometer should then be raised rap-
idly and decreased slowly, as in the palpatory
method, until a sound is heard with each heart beat. Note the reading as systolic pressure.

As a rule, systolic pressure determined by the auscultatory method is higher than the pressure at which radial pulse beats are first palpable. In case the palpatory reading should be higher than the auscultatory, a number of maneuvers may be undertaken to improve conditions for hearing the sounds. (See appendix II.B.) If, despite such efforts, the pressure read by palpation continues to be higher, it should be accepted as the reading for systolic pressure. This should be noted.

V. Determination of Diastolic Pressure by the Auscultatory Method. With continued deflation of the system below systolic pressure at a rate of 2 to 3 mm. Hg per heart beat the sounds undergo changes in intensity and quality. As the cuff pressure approaches diastolic the sounds often become dull and muffled quite suddenly and finally cease. It appears that the point of complete cessation is the best index of diastolic pressure. (See appendix III.) Under hemodynamic conditions in which no cessation of sounds occurs, the point of muffling should be taken as diastolic pressure, if distinctly heard, and should be recorded as the point of muffled sounds. When no clear demarcation of the muffling is heard, diastolic pressure should be left indefinite and so indicated, for example, 150/30.

VI. The Operator. A number of consecutive determinations of systolic and diastolic pressure should be made and, if they agree reasonably well, the average should be taken. Variations in auditory acuity are important. A physician aware of defective hearing should use an amplifying stethoscope. Auditory acuity is of importance in subtler ways. The first sounds that occur at systolic cuff pressures and the last ones to occur in determinations of diastolic pressure are exceedingly feeble and of short duration. Physicians improve their acuity by training, but personnel to whom blood pressure determinations are often relegated do not have equivalent auscultatory experience.

Appendix

I. The rate of pressure fall suggested is not only convenient in detecting the precise cuff pressures at which sound phenomena occur but, in the case of portable mercurial manometers commonly employed, it should not be faster. Many mercurial sphygmomanometers contain a porous covering over the manometer tube to prevent spilling of mercury when folded into a case. This reduces the rate of air flow through the porous covering which tends to develop a negative pressure above the mercury column and prevents equalization of pressure with the cuff when the mercury column drops too fast. On the other hand, too slow a release of pressure tends to cause intermittent trapping of blood between systolic and diastolic levels.

II. The following maneuvers are often helpful in improving the distinctness and quality of sounds:

(A) Slight variations in pressure and shifts in the position of the stethoscope receiver. Firm application of the receiver often facilitates recognition of the first sounds in determination of systolic pressure; but compression of the artery by a receiver must be avoided in determination of diastolic pressure. Occasionally better sounds are heard on the upper arm just above the antecubital space (owing to existence of aberrant arteries (?)).

(B) Avoidance of congestion in arm veins. Congestion stultifies the auscultatory criteria both by lowering the level at which sounds appear and by causing them to drop out when the cuff pressure is between systolic and diastolic (auscultatory gap). Clothing should be adjusted to avoid constriction and the cuff should not be inflated when the arm is pendant. If there is any sign of the auscultatory gap the observation should be repeated by filling the cuff when the arm is upraised.

III. The recommendations formulated in 1939 contained the suggestion that two values for diastolic pressure be recorded; for example, 140/80–70. It is the impression of the Committee that such a practice has not been followed very generally. It doubts, on the grounds of hemodynamics, the propriety of listing two figures as "diastolic pressure." The disappearance of auscultatory sounds as a criterion of diastolic pressure is recommended on the following grounds:

(A) The current practice of using the point
of sudden muffling of the sounds was based (1) on comparisons with oscillatory criteria, and (2) on hemodynamic data derived from studies of excised or isolated arteries undergoing direct compression or decompression. The former (1) is of dubious value since no general agreement has been reached regarding the oscillatory criteria of diastolic pressure. The latter (2) appears to be risky owing to the fact that unsolved physical factors may enter when pressure is transferred to arteries from a cuff of arbitrary size through the tissues of a limb.  

(B) While some difficulties still exist in making absolute comparisons between pressures determined by optical manometers and those revealed by auscultatory criteria, a limited number of such comparisons strongly suggests that, on the average, the cessation of sounds conforms rather better to the intra-arterial diastolic pressure and that dulling of sounds appears 5 to 10 mm. Hg above this level.  

(C) Accuracy, not applicability to every individual, should determine the choice of criteria. The fact that sounds may persist as cuff pressure is reduced to lower levels, or even to zero, in certain clinical states, such as aortic insufficiency, hyperthyroidism, anemia, and in an occasional normal person, should not determine the selection of an equivalent criterion for diastolic pressure if it is not exact. The fact remains that cessation of sounds does occur in a very large percentage of all individuals examined. It is therefore recommended that the less exact criterion of muffled sounds be used only when necessary and that such readings be recorded as the point of muffled sounds. If any significance is attached to the fact that sounds are heard below this point, it should be recorded.  

(D) Tests of different examiners reveal that, probably owing to different degrees of auditory acuity, there is a greater uniformity in decisions as to when sounds cease than as to the point at which they begin to muffle. Hence greater uniformity in recording diastolic pressures and enhancement of their accuracy in any statistical study may be expected by using disappearance of sounds as a criterion. Furthermore, the distinctness or demarcation of the dulling phase varies in different subjects examined. Frankness must cause us to admit that all too frequently the reading of diastolic pressure by this criterion becomes merely a guess.  

IV. Arrhythmias and Dyspnea. The determination of blood pressure in arrhythmias and in pulsus alternans is unsatisfactory at best. An occasional premature contraction can be ignored. When continued irregularity occurs, as in auricular fibrillation or coupled beats, or in cases of pulsus alternans, the readings at which sounds appear and disappear in the stronger and weaker beats should be recorded. A similar procedure may be followed in patients with dyspnea.  

V. Basal Blood Pressures. When special studies of blood pressure are required, determinations should be made under basal conditions similar to those used in metabolic studies. A convenient way to accomplish this is to determine the patient's blood pressure before breakfast and before arising in the morning. Alternatively it may be made in the office 10 to 12 hours after a meal and after the patient has reclined for at least 30 minutes in a comfortably warm room.  

VI. Blood Pressure in Thighs. Measuring the pressure in the thigh arteries poses difficulties that have not been solved. The exact cuff size for thighs of different size has never been worked out. In normal persons one guiding principle should be kept in mind, namely, systolic pressure in the thigh by intra-arterial measurement may be 10 to 40 mm. Hg higher than in the arm, but diastolic pressure is essentially the same. If one uses apparatus on a normal individual in which the thigh diastolic reading is higher than arm diastolic reading, the cuff width should not be trusted to give correct readings. In coarctation of the aorta, systolic pressure is very much lower and diastolic pressure a little lower in the thigh than in the arm. This cannot be truly recognized with a cuff that has not been tested carefully on a normal thigh of the same size as that of the patient.  

VII. Multiple Blood Pressure Determinations. When anomalies of the large arteries are suspected or an unexplained hypertension exists in a brachial artery, pressure readings should be made in both arms and in one or both thighs.
It is suggested that the blood pressure of a new patient be taken in both arms.

**Documentation**

Brief summaries of the pertinent literature since 1930 upon which the foregoing recommendations were based are appended. Although Bazett's studies pertained largely to oscillatory criteria, his communications contain information of general applicability and are therefore included.


"A comparison of blood pressure measurements made simultaneously directly on the right femoral artery and indirectly by a modified Riva-Rocci method on the left thigh in dogs is described. Both records were made optically. The indirect oscillatory method was demonstrated to be accurate for end systolic pressure whether a single or double bag system was employed, provided that a clear criterion was demonstrable, and that the bags were of proper size and properly applied. . . A single bag or a double bag system should compress the thigh for a length of at least 12 cm. in dogs of 12 to 18 kg. weight. In a double cuff system the upper bag must have a breadth of at least 5 cm. Cuffs of similar size are probably suitable for use on the human adult arm . . . Changes in blood pressure are produced by inflation of a cuff, partly from mechanical obstruction of a large area, partly through reflex adjustments to this obstruction. These changes rarely exceed 5 to 10 mm., with occlusion of the thigh in the dog; in man with occlusion of one arm the effects are probably less than this . . . During rapid deflation, profound local changes may occur in the pressures in the vessels previously compressed. Both lateral systolic and lateral diastolic pressures are reduced, probably as the result of absorption of pressure energy through the induction of a rapid velocity head into the empty vessels below the cuff. In consequence all measurements by indirect means of the lateral pressure levels are too low, unless the deflation is conducted slowly. Moderately slow deflation and consequent congestion do not introduce serious errors. Deflation at a rate of 2 or 3 mm. per second is recommended . . . Some values for differences between end and lateral pressures in the femoral artery of dogs are given: . . . The systolic difference with a pulse pressure of 52 mm. amounted, on the average, to 18 mm.; in the presence of aortic regurgitation with a pulse pressure of over 100 mm., to one of 20 to 40 mm. In diastole the end pressure might be 2 mm. below or 13 mm. above the lateral pressure; the mean value was 4 mm. above it."


"It has been shown in a schema, and also in dogs, that the process of compression of a segment of the vascular system by an air column alters the actual pressures within the system at compression pressures which exceed diastolic pressure. Diastolic pressure is raised particularly at pressures just above the diastolic level; systolic pressure is lowered at pressures below the systolic level, raised at pressures above it. At the true lateral systolic level these two effects more or less neutralize one another. The changes are shown to be modified by the volume of the compressed segment. The raising of diastolic pressure and lowering of systolic result from the decreased volume-elasticity coefficient created by the air column; the ultimate rise in systolic pressure depends on the stoppage of the flow and reflection of the primary wave; this second change is only brought gradually into action by an air compressing system, owing to the cushioning effect of the air column . . . The effects of compression on diastolic pressure may be very unequal in the two separated parts of the main system. When separation is effected, the pressure changes proceed independently in the two sections according to their own volume-elasticity coefficients and rates of outflow. The peripheral pulse pressure tends to be the greater owing to the lengthening of the diastolic period in this section, and the consequent fall of diastolic pressure to a lower level, but the whole picture may be altered by the direction in which the contents of the compressed segment are mainly discharged. In general this discharge is towards the side which has the slower rate of fall of pressure . . . The flow of fluid along the angles of compressed arteries is denied; fluid transmitted at compression pressures, which exceed the lateral systolic pressure, does so in the form of a wave of 'bolus' type."


Cubital pressure was recorded with the Broemser glass plate optical manometer from one arm, together with respiration, and estimated systolic and diastolic pressures on opposite arms by appearance of sound and cessation of pure sound quality. In 44 registrations of patients with various clinical disorders they found that systolic and diastolic pressure comparisons can correspond under some conditions. Very often, however, auscultatory readings are higher or lower than directly recorded pressures. The pulse pressure tends to be too low by the Korotkow method. Respiratory variations
of several mm. Hg occur during natural respiration; these become greater, the deeper and slower that respiration becomes . . . The following reasons are suggested for discrepancies:

"Under otherwise similar conditions pulse waves of different forms are suppressed with variable facility. In determining diastolic pressure by auscultatory methods the results are apt to be affected by the ability of the vascular system to undergo vibrations. Other technical errors obviously enter."


Thirty comparisons between intra-arterial pressures and pressure readings by the cuff method indicate that the indirect method is 3 to 4 mm. Hg too low in evaluating the brachial systolic pressure and 9 mm. Hg too high for diastolic pressure.


The use of the pediatricians cuff (4.5 cm. wide) gave palpatory readings 20 to 25 mm. Hg too low. (The auscultatory method cannot be used in infants.)

Trying narrower cuffs, the authors could get agreement with direct intra-arterial recordings of the umbilical systolic pressure only when the cuff was 2.5 cm. wide. Comparisons were made in 37 newborn babies. Recent authors (quoted) have given values, using wide cuffs, that are lower (systolic) than mean pressures recorded by cannulating the umbilical artery.


Since the cuff width is of importance in the reading of blood pressure in infants it was expected that cuffs as used in children might be either too wide or too narrow to give correct readings of systolic and diastolic pressure. The proper width of cuff increases with the circumference and with the length of the arm and probably decreases with its compressibility. All these factors vary in such a manner that the proper width of cuff increases with age. It is suggested that three cuffs be used for children. The average of 22 determinations in normal new babies was 1.3 mm. Hg lower than the average determination of umbilical systolic pressure. The average error of a single determination was 3.6 mm. Hg.

The 5 cm. cuff was used in 12 children less than 1 year old gave average figures that differed 0.3 mm. Hg from the average brachial systolic pressure. For diastolic pressure the average reading was 11 mm. Hg too high. The average error of a simple determination was ±0.5 mm. Hg systolic and ±11 mm. Hg diastolic.

The 9 cm. cuff gave in 34 children 1 to 13 years old a figure that was 2.1 mm. Hg (systolic) too low, and 4.6 mm. Hg (diastolic) too high. The average errors of a single determination were ±5.1 mm. Hg systolic and ±7.3 mm. Hg diastolic.

Either systolic or diastolic readings could be made to agree with direct measurement by choosing a proper cuff width. The same cuff width would not do for both pressures. Three widths above were chosen to give a reasonably close figure for readings of both systolic and diastolic pressures.


"While he is determining blood pressures of standing patients by the usual auscultatory method, the physician frequently finds the auscultatory sounds to be very indistinct. Occasionally, sounds cannot be heard. Under these circumstances it will be difficult or even impossible to determine blood pressure. Such impairment of sounds seems to be referable to venous congestion distal to the cuff of the sphygmomanometer.

"If the arm of a standing patient is raised above his head until the veins are relatively empty, if the cuff of the sphygmomanometer is then inflated so that a value exceeding that of the systolic blood pressure is obtained, and if the patient's arm is then lowered, impairment of auscultatory sounds will be prevented and determination of such a patient's blood pressure will be simplified."


"The commonly employed clinical method of measuring blood pressure should not be looked upon as a truly accurate procedure. In most adult subjects it provides reasonably reliable information, but in a significant number of cases the information may be quite misleading. Misinformation is particularly likely to be obtained in subjects with unusually large or unusually small arms; if the arm is small, the clinical estimate of the systolic pressure is likely to be too low; if the arm is large, the clinical estimate of both systolic and diastolic pressure is likely to be too high. The error in either direction may exceed 30 mm. Hg.

"The foregoing observations must be borne in mind whenever it is necessary to come to a decision concerning the diagnostic or prognostic significance of minor depressions or elevations in the level of the blood pressure. Statistical studies of the relation between blood pressure and body weight should take into account the influence of the circumference
of the arm upon the accuracy of the blood pressure measurements.

"ADDENDUM. Note on the 'Auscultatory Gap'. The phenomenon known as the 'auscultatory gap' which is noted at certain times and in certain patients during the measurement of arterial pressure by the usual auscultatory method has been recognized by clinicians for many years... When the cuffs encircling the two arms were inflated rapidly so as to avoid venous congestion distal to the cuffs, no auscultatory gap occurred as the cuffs were subsequently deflated. On the other hand, when inflation was carried out gradually, a well-marked auscultatory gap was noted during deflation. A very striking difference may be noted between the intra-arterial pressure tracings in the two records. After rapid inflation of the cuffs the intra-arterial pressure fell some 45 mm. Hg below the diastolic pressure level in the unoccluded artery; as the cuffs were deflated, the intra-arterial pressure rose steadily but the diastolic pressure below the occluding cuff never rose appreciably above the diastolic level in the unoccluded artery. After the slow inflation of the cuffs the intra-arterial pressure did not fall so low, and as the cuffs were deflated the intra-arterial pressure rose rather rapidly and the diastolic pressure below the cuff reached a peak which was well above that of the diastolic pressure in the unoccluded artery.

"These observations are recorded here to note the fact that prolonged partial occlusion of the veins of the arm during the inflation of a blood pressure cuff affects the arterial as well as the venous pressure distal to the cuff. The effect upon the arterial pressure may be the determining factor in the production of the auscultatory gap."


"Concerning the comparison of simultaneous measurements of arterial pressure obtained by direct intra-arterial manometry and by indirect auscultatory technique in 39 individuals, it may be said that: 1. Systolic pressure was underestimated in indirect measurement by about 10 mm. Hg. In the present study, the indirect pressure in the brachial was compared with the direct pressure in the radial artery. This procedure may account for half of this difference. 2. In auscultatory technique the disappearance of sound proved to be a more accurate measure of diastolic pressure than the sudden muffling. The former overestimated diastolic pressure by 8.8 mm. Hg, the latter by less than 1. 3. The indirect auscultatory method of estimating arterial pressure is, considering its convenience and simplicity, an unusually accurate bedside method."


"The effects of inflating a cuff upon arterial and venous pressures distally were studied by use of the Hamilton manometers. Of interest to our project was the observation that when cuffs were inflated to pressures between diastolic and systolic, and maintained at these pressures, the cuff isolated the distal tree intermittently and caused an elevation of diastolic pressure peripheral to the cuff. These observations would seem to stress the importance of not maintaining rising and falling cuff pressures in this zone for too long a period in routine determinations of blood pressure."


"1. The systolic blood pressure in the arm can be measured with reasonable accuracy in most subjects with normal pressure, hypertension, and aortic regurgitation by the ordinary arm cuff and auscultatory technique. 2. The brachial diastolic pressure, as measured by the ordinary cuff, is usually too high, especially in aortic regurgitation. 3. The femoral systolic blood pressure cannot be measured accurately with the ordinary 13 cm. cuff. A wider (15.5 cm.) cuff permits more accurate measurement of the femoral systolic pressure except in subjects with aortic regurgitation whose pressures cannot be measured accurately with either cuff. 4. Femoral diastolic pressures obtained with either cuff were grossly inaccurate in all subjects. 5. The difference between the blood pressure in the arm and leg in patients with aortic regurgitation is not so marked as is generally believed because the cuff, wide or narrow, does not allow true measurements of femoral pressure. Therefore, it is probable that no diagnostic value should be attributed to this sign."