Blood Pressure & Hypertension

What is blood pressure?

Blood pressure is the arterial pressure of the blood caused by the heart forcing the blood through the arteries. High blood pressure is characterized by abnormally elevated blood pressure in the arterial system.

In 1733, an English clergyman, Stephen Hales, first quantitatively measured blood pressure. By inserting a brass tube connected to a 9-foot long glass tube into the crural artery of a horse, Hales observed that the column of blood rose and fell with each pulse beat, sometimes as high as 8 feet.

Changing with every contraction of the heart, the pressure in the arteries is the highest when the heart contracts and sends blood coursing through the circulatory system, and the lowest as the heart relaxes to fill with blood as it prepares for another contraction.

The 2 phases of filling and contracting of the heart are termed:

SYSTOLE and DIASTOLE

SYSTOLE occurs during the contraction of the heart.

DIASTOLE occurs during the relaxation and filling of the heart.

The pressures resulting from blood flow in the arteries are known as SYSTOLIC and DIASTOLIC, and are recorded as a ratio. This is expressed as 120/80 or SYSTOLIC/DIASTOLIC. The numbers reflect measurements taken in millimeters of mercury (mm Hg).

What is normal blood pressure?

"Normal" blood pressure cannot be precisely categorized, but a pressure of 120/80 mm Hg is usually considered acceptable for a healthy adult. However, if the subject is a young, healthy athlete, a blood pressure of 95/60 might be indicative of normal. Also, an elderly male, non-smoker, good health, normal weight, could have a pressure of 140/90 and still be considered within the safe blood pressure ranges for his age. Generally, the lower the diastolic blood pressure, the better.

What are the symptoms of high blood pressure?

High blood pressure usually does not produce symptoms (asymptomatic). A few individuals may experience morning headaches or dizziness with severe high blood pressure. However, the only way to be sure is to have the individual's blood pressure checked regularly.

What is hypertension?

Hypertension is among the most common disease in the world. In the U.S., it affects over 60 million individuals; one in nearly 5 U.S. citizens is a victim of this silent killer. To that number can be added the still uncounted millions of potentially hypertensive individuals with "High Normal" diastolic blood pressures.

Physicians categorize the types of hypertension into Primary, Secondary, Essential, and Labile.

Primary Hypertension: an inherent form of hypertension, apparently developing on its own, without the influences of other primary diseases or physiological conditions.

Secondary Hypertension: refers to sustained elevated blood pressures that have been caused by other influences such as pregnancy, primary disease, or medication. Detected early, secondary hypertension, that can be a fleeting case of situation elevated blood pressures, is easily controlled if not reversible with proper management.

Essential or Severe Hypertension: occurs after sustained elevations of blood pressure have remained unchecked and physiological breakdown begins. This disease state is controllable with aggressive treatment measures, but it is often not detected until end-organ damage has begun.

Labile Hypertension: a term often used in referring to elevated blood pressures. Labile can be indicative of either primary or secondary hypertension. In either instance, it refers to the "difficult to diagnose" pressures that do not appear to be consistent from day to day. This also complicates treatment.

Finally, to round out the basic terminology surrounding hypertension, there is one more blood pressure definition which should not be overlooked. HYPOtension, which is the opposite of HYPERtension.

Hypotension is a condition indicative of blood pressures that are too low. This can result in a lack of oxygen throughout the system, causing dizziness and fatigue, or syncope (fainting). Hypotension may be a secondary result of various anti-hypertensive drugs, and is considered a symptom of pacemaker syndrome (a condition that affects many new recipients of internal cardiac pacing devices).

What causes hypertension?

There is no known cause for hypertension, but there are many conditions that may lead to its development. Obesity, age, diet, nervous disorders, genetic make-up, stressful lifestyle, and primary disease may lead to the onset of hypertension. Generally, any condition, including organ transplant or pharmaceutical intervention, which changes the thickness of viscosity of the blood as it flows through the arteries will affect the pressure of blood. Whenever the blood pressure rises and remains elevated, hypertension has the potential for evolution. If left untreated, the time from hypertension onset to death is approximately 20 years. Occurring silently, painlessly, and without warning, many do not know they have the disease until they experience its inevitable organ-damaging effects. Once organ failure begins, the hypertension is already in its final stages and the patient can expect only a few years to live unless aggressive disease management is undertaken.

What are the effects of hypertension?

High blood pressure is an extremely serious condition because of its long-term effect on all of the body's vital organs. The heart, brain, kidneys, and blood vessels are among the most commonly affected organs. High blood pressure adds to the workload of the heart and arteries.

- The Heart: forced to work harder than normal and tends to enlarge and is unable to function properly.

- The Brain: as blood pressure increases, damage occurs to the lining of the blood vessels in the brain and small blisters (aneurysms) may form. Aneurysms can burst suddenly causing a "stroke" - resulting in a hemorrhage in the brain.
- The Kidneys: hypertension can cause narrowing and thickening of arteries in the kidneys, reducing the amount of fluid that the kidneys can filter. Waste products from the body begin to accumulate. Eventually, the kidneys will fail completely.
- The Blood Vessels: If blood pressure is not controlled, some of the fat that normally circulates in is pushed more rapidly into the walls of the arteries. Plaque accumulates in the arteries, like rust on the inside of a pipe. Although plaque accumulation is also caused by other factors, hypertension does not help.

Why is hypertension difficult to diagnose?

Part of the reason why hypertension may be difficult to diagnose and manage is because neither systolic nor diastolic pressures are static, both are affected by the activities of the entire cardiovascular system, and in a normal or "normotensive" individual, each has a distinct pattern or "circadian " rhythm that is repeatable day after day.

Continuous invasive or intra-arterial blood pressure monitoring has shown conclusively that usually normotensives experience 2 peaks in blood pressure, evident during each 24-hour period. One peak occurs mid-morning for approximately 1 hour and another in the mid-afternoon followed by a steady fall in pressure through the night. The pressure will reach its lowest point usually between 3:00 and 6:00 A.M. The pressure begins to rise slowly until the hour of arousal when it accelerates rapidly, once more rising to the peak for the day.

During the lowest depression of the night or "nocturnal" pressure, the systolic pressure can drop as low as the highest diastolic pressure value during the mid- morning peak.

The greatest and most volatile changes in blood pressure occur in response to the external environment. Blood pressure is known to vary considerably during the day, depending on the physical activity, psychological stress, and environmental factors, and can fluctuate a much as 40 mm Hg daily.

Seasonal changes in blood pressure also occur in relationship to the blood level of aldosterone in the human body. The hormone, secreted by the adrenal gland, affects blood volume through the body's retention of sodium and its excretion of potassium. Aldosterone is usually slightly higher in the winter and lower in summer, subsequently causes higher winter pressures and lower pressures during summer months.

Another very important fluctuation in blood pressure may occur in the physician's office when the measurement is being taken to determine a diagnosis of hypertension. This psychological response of the blood pressure is known as "white coat" syndrome. In the presence of medical personnel, some individuals with otherwise normal blood pressure have abnormally high readings. The pressures can be up to 20 mm Hg higher than if they were in their routine environments. Conversely, overcompensation of the psychological system can cause patients who otherwise have pathologically high blood pressures to present low or normal blood pressures in the presence of medical personnel.

Despite all of the evidence that multiple measurements of the blood pressure are indeed necessary to accurately diagnose and treat hypertension, the fact remains that office

measurements continue to be the most routine means of diagnosis and therapy, and many patients are not only mislabeled as hypertensive, but often undergo unnecessary or inappropriate treatment or not treated at all.

Blood Pressure Measurement

How is blood pressure measured?

Blood pressure may be measured directly or indirectly. The direct or invasive intra-arterial method is used for physiological research and is carried out by introducing a miniature manometer or catheter into the lumen of an artery. The catheter is connected to a blood pressure transducer, which converts mechanical energy into electrical energy. In turn, this is used to produce a visual display of the blood pressure.

Because this method can effectively record every blood pressure generated with every beat of the heart, direct monitoring is believed to be the most accurate method of blood pressure detection and is considered the gold standard by which to measure the accuracy of other blood pressure measurement devices and methods.

The first indirect device for measuring arterial blood pressure was designed in 1854. In 1896, Riva Rocci added the pneumatic cuff to the upper arm for obliteration of the radial pulse. The inflated cuff was used to occlude the brachial artery, causing the radial pulse to disappear. The blood pressure in the artery was determined when the pressure in the cuff was slowly released and radial pulse reappeared.

Only nine years later in 1905, a Russian physician by the name of Korotkoff described the tapping and murmuring sounds heard while using a stethoscope over the brachial artery while it was occluded by a pneumatic cuff[1]. This discovery gave birth to modern sphygmomanometry, using a mercury column and the auscultatory method of identifying blood pressure.

Auscultatory measurements are made with the help of a stethoscope which allows for the auditory sensing of blood rushing through the brachial artery. As the Korotkoff or K-sounds are identified by the observer taking a blood pressure measurement, the level of mercury on a mercury column (or the meter point on an aneroid manometer) is recorded. The following is a description of these sounds as they were first heard by Korotkoff in 1905.

Phase 1	A series of short tapping sounds	**SYSTOLIC BP**
Phase 2	Swishing	
Phase 3	Knocking	
Phase 4	Muffling	
Phase 5	Silence	**DIASTOLIC BP**

Phase 5 is generally accepted as the point for diastolic determination in the United States. In Europe and in studies involving children, Phase 4 is the preferred point for diastolic determination.

Today, another technique called oscillometry may also be used. Oscillometric measurements are made with the use of a blood pressure cuff and tactile sensors which measure pressure waves in the cuff as blood surges through the constricted artery.

In all methods of measuring blood pressure with standard manual sphygmomanometry equipment, it is necessary that proper techniques and use of the equipment be observed. Reports on the use of conventional mercury or aneroid sphygmomanometers show that as many as half of

those used in hospitals and clinics are inaccurate or faulty and that most facilities have no policy for maintaining the equipment[2]. Even with properly functioning equipment and correct techniques, there are several sources of error that can adversely affect the accuracy of measurements. There are the additional pitfalls of observer bias, terminal digit preference and concerns with visual and auditory acuity.

Often the misinterpretation of Auscultatory Gap, a lack of K-sounds mid-way between any of the five phases, is also an area where observer error can be significant. If, for example, this gap is mistaken for Phase 5 and the diastolic pressure is noted at that point, the diastolic pressure may be as much as 30 mmHg higher than the actual measurement.

For these reasons, a number of new devices and techniques for blood pressure measurement have emerged. In recent years, increasing reliance has been placed on automated devices to measure blood pressure indirectly. These devices allow for measurements to be taken in the patient's natural environment outside of the physician office. These data more accurately reflect the patient's actual blood pressures and thus allow for better diagnosis and patient management.

What is the Auscultatory Method?

Blood pressure is measured by using a sphygmomanometer and an occluding cuff. Pressure of blood in the artery is balanced by pressure from air in a cuff wrapped around the upper arm, over the brachial artery. What is measured is actually the pressure in the cuff. The steps to obtain an accurate blood pressure are as follows.

1. The cuff is wrapped securely around the arm, about 1-2 inches above the antecubital (elbow) crease. The middle of the cuff bladder should be over the brachial artery.

2. The radial artery is palpated just above the base of the thumb, while air is pumped into the cuff until the pressure in the cuff is elevated to 20-30 mmHg above the arterial systolic pressure. The higher cuff pressure collapses the brachial artery, halting blood flow into the lower radial artery. With no blood able to flow through the artery under the cuff bladder, the brachial and radial pulse disappears.

3. A stethoscope is placed just below the cuff over the brachial artery. The air is slowly released from the cuff at 3-5 mmHg per second. As soon as cuff pressure falls below systolic pressure, faint tapping sounds can be heard in the stethoscope as blood begins to pulse through the artery again. These are the Korotkoff or K-sounds (Phase 1). As soon as they are heard, the pressure level indicated by the manometer is noted and recorded as the systolic blood pressure. Korotkoff sounds are believed to be caused by blood jetting through the partly occluded vessel. The jet causes turbulence in the open vessel beyond the cuff, setting up vibrations heard through the stethoscope.

4. The Korotkoff sounds continue to be heard as tapping sounds as the air is further released from the cuff at 3-5 mmHg per second, until the cuff pressure drops below the diastolic pressure. With the cuff pressure below this level, the artery no longer closes during diastole. This indicates the turbulence caused by the blood jetting through the squeezed artery is also no longer present. Therefore, the tapping sound suddenly changes to a muffled quality, with the sounds usually disappearing altogether in another 5-10 mmHg. The diastolic pressure is the level noted on the manometer after the sound becomes muffled (Phase 4) and then ceases (Phase 5).

Common Error in Indirect Blood Pressure Measurement[3]

1. Observer error - problems such as habitually reading higher or lower, terminal digit preference, auditory acuity.
2. Equipment error - poor condition, non-calibrated manometers, dirty tubes/vents.
3. Technique error - inappropriate cuff size, inappropriate rate of deflation, lack of rest period[4].

Indications & Clinical Utility of ABPM

Office or White Coat Syndrome[5]

This phenomenon is exhibited by patients who have elevated blood pressure measurements only when they are in the physician's office. Upon their return to their normal environment (home, work, etc.), their pressure returns to normal. Many physicians rely on the home or self-measurement method to identify the phenomenon. However, many times the instruments the patients will use are poor quality and or the patients are unable to perform the measurement correctly (due to hearing acuity, etc.).

This is an excellent application for ABPM. ABPM eliminates the need for a home device, training of the patient, and affords the physician more data points (including sleep) from which to develop an accurate assessment of the patient's condition.

High Normal Blood Pressure with Target Organ Involvement[1]

This is the opposite of 'White Coat''. In this case the patient's blood pressure is borderline or high normal in the office. In addition to the high normal blood pressure, there is evidence of target organ damage (e.g., abnormal renal function, left ventricular hypertrophy, etc.). However, upon return to their environment the blood pressure is elevated. This can be due to physical activity or mental stress (e.g., work-related stress).

ABPM is effective in identifying these types of patients as well as the activity or environment that induces the high blood pressure.

Resistant Hypertension[1]

Resistant hypertension is often diagnosed when multiple anti-hypertensive medications fail to control high blood pressure as measured in the clinic or office. Here again, the office pressure may not be representative of the pressure over the course of the entire day. ABPM can demonstrate the degree and duration of anti-hypertensive agents in these types of patients.

Episodic Hypertension[1]

Episodic hypertension may be caused by certain anxiety syndromes and can be confused with pheochromocytoma (a disorder of adrenergic excess due to a tumor, in which the pressure is consistently elevated). Careful matching of patient activity diaries with ABPM data often aids in the diagnosis of episodic hypertension.

Evaluation of Hypotensive Symptoms[1]

Some anti-hypertensive drug therapy may induce a hypotensive (low blood pressure) condition. This may go undetected due to relatively normal office readings after medication indicating the medication is controlling the hypertension. However, upon leaving the office the patient becomes hypotensive. ABPM can help the physician recognize the extent of over or under treatment.

Also, patients with autonomic dysfunction have a unique ABPM profile. E.g., hypotensive episodes with change in posture, low blood pressure during awake hours, supine hypertension even while asleep, abrupt and large reductions in BP after meals, and little or no variations in

heart rate in association with falls in BP. Carotid sinus syncope and pacemaker syndromes can be more easily assessed when ABPM and ECG monitoring are performed simultaneously.

Assessment of Anti-hypertensive Drug Therapy[6–7]

It is impossible to assess the duration of anti-hypertensive activity accurately with simple, casual office measurements. Many physicians take frequent casual BP measurements or have patients take doses in outpatient clinics and wait in the facility for peak effects and return for trough measurements. ABPM is a useful clinical tool that is unobtrusive and easy to use in this application.

Hemodialysis volume Independent Patients[8]

Many hemodialysis patients are thought to have elevated BP due to inadequately controlled volume. ABPM can assist in identifying those patients who are volume independent hypertensive.

In addition, hemodialysis patients with chronic hypertension are sometimes poorly controlled by anti-hypertensive drugs. The proper assessment of hypertension in the hemodialysis patient requires multiple measurements of BP along the dialysis cycles. ABPM can provide a useful tool to the nephrologist in managing the hypertensive hemodialysis patient.

Hypertension during Pregnancy

ABPM can provide useful blood pressure information in pregnant women. 24- Hour blood pressure is significantly elevated during weeks 36-38 when compared to weeks 18-22 and 30-32 of gestation. ABPM can monitor this phenomenon and assist the physician in reliably evaluating the BP during pregnancy.

ABPM can also identify the "White Coat" patients from the true hypertensive patients and provide a useful tool for serial BP measurements in those patients with high-risk factors or actual preeclamptic (a toxemia of late pregnancy, characterized by hypertension, albuminuria, and edema) conditions.

Types of ABPM Technology

Level I: Oscillometric Technique

Originally developed to detect Mean Arterial Pressure or (MAP); Popularized by Johnson & Johnson division Critikon, in the stand-alone device called Dynamap. Widely used in anesthesiology for an indication of perfusion during surgery. It was adapted by Spacelabs for ambulatory blood pressure.

Oscillometry works by sensing the pressure changes in the cuff only and utilizing a proprietary algorithm to calculate the systolic and diastolic values. The largest oscillation detected is assumed to be the Mean Arterial Pressure. The algorithm then uses a regression curve analysis to determine the systolic value. Once the MAP and Systolic values have been determined, the diastolic value is calculated by solving for'd' in the formula 2d + s / 3 = M. In addition, most oscillometric devices do not employ a linear deflate. The deflate is a stair-step dropping at 8 mm Hg/second. In spite of the opportunities for error, the oscillometric devices do a good job of detecting the MAP (the original design objective). However, the systolic and diastolic values can leave much to be desired.

Advantages: Easy Hook-up

Disadvantages: Calculated systolic and diastolic values, not a direct measurement[9]; Non-linear deflate; very sensitive to movement (originally designed for immobile patients)

Level II: Auscultatory Technique

These devices utilize a microphone to detect the Korotkoff sounds ("K" sounds) in addition to sensing pressure changes in the cuff. It also employs a proprietary algorithm. These devices are generally more accurate than the oscillometric devices due to the detection of "K" sounds.

However, movement can affect the readings since the "K" sounds detected do not have a physiological reference.

This technique has been adapted by Welch Allyn, Instromedix, BioAnologics, and Takeda (A&D). Oxford, Del Mar, and Novocor employ this technique when not using ECG electrodes.

Advantages: More accurate than oscillometric; Convenient Hook-up

Disadvantages: Sensitive to movement and microphone placement; May not use linear deflate; Less accurate measurement of Systolic and Diastolic10⁻11⁻12

References

[1]How Korotkoff, the Surgeon, Discovered the Auscultatory Method of Measuring Arterial Pressure, Harold N Segall, Annals of Internal Medicine, Volume 83, 1975

[2]Sphygmomanometers in hospital and family practice: problems and recommendations, M J Burke, Helen M Towers, K O'Malley, D J Fitzgerald, E T O'Brien, British Medical Journal, Volume 285, August 1982

[3]A Review of Common Errors in the Indirect Measurement of Blood Pressure, Richard H Bailey, MD, John Bauer, MD, Arch Intern Med, Volume 153, 1993.

[4]Clinical Assessment of blood pressure, D W McKay, N R C Campbell, L S Parab, A Chockalingham, J G Fodor, J Hum Hypertens 1990;4:639-645.

[5]National High Blood Pressure Education Program (NHBPEP) Working Group on Ambulatory Blood Pressure, U.S. Dept. of Health and Human Services, NIH Publication No. 90-3028, 1990

[6]Methods of Blood Pressure Determination to Assess Antihypertensive Agents: Are Casual Measurements Enough?, William B. White, M.D., Clinical Pharmacology & Therapeutics, Vol.. 45, No. 6, 1989.

[7]Analysis of Ambulatory Blood Pressure Data in Antihypertensive Drug Trials, William B. White, M.D., Journal of Hypertension, Vol 9 (suppl 1), 1991.

[8]How Well is Hypertension Controlled in Hemodialysis Patients?, Jhoong S. Chigh, M.D., Seminars in Dialysis, Vol. 5, No. 2, 1992.

[9]Ambulatory Blood Pressure Monitoring: Clinical Uses, Michael A. Weber, M.D., University of California Irvine, Hospital Practice, July 15, 1992.

[10]A Systematic Error with the Spacelabs 90207 Ambulatory Blood Pressure Device, C.E.Grim, C. Mohan, American Journal of Hypertension, Vol. 5, No. 5, Part 2.

[11]Bias & Variability in BP Measurement: Implications for Epidemiology, G. Pannarate, S.J. Clark, B.G. Sullivan, C. Foster and J. Coats, American Journal of Hypertension, Vol. 10, Supplement 4.

[12]Effect of Patient Variables on Validity of Spacelabs 90207 Automated Ambulatory Blood Pressure Monitor (AABPM), R. Zacest, Journal of Hypertension, Vol. 10, Supplement 4.

6901 E. Fish Lake Road, Suite 188, Maple Grove, MN 55369
+1.800.465.8408 | +1.763.559.8492 | *fax* +1.763.559.2961
info@QRSdiagnostic.com | www.QRSdiagnostic.com