Equipment Packet: Blood Pressure Monitor

UMDNS #: 13106

Date of Creation: September 16, 2015

Creator: Compiled by Cassandra Stanco for Engineering World Health (EWH)

Equipment Packet Contents:

This packet contains information about the operation, maintenance, and repair of blood pressure monitors.

Part I: External from the Packet:

Part II: Included in this Packet:

1. Operation and Use of Blood Pressure Monitors

Featured in this Section:

WHO. "Blood Pressure Monitor," From the publication: *Core Medical Equipment*. Geneva, Switzerland, 2011.

Wikipedia, "Blood Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

Wikipedia, "Pulse Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Pulse_pressure

Blood pressure monitor **Blood Pressure Monitor Brief Overview**

UMDNS		GMDN	
18325	Sphygmomanometers, Electronic, Automatic, Auscultatory	16173	Automatic-inflation electronic sphygmomanometer, non-portable
18326	Sphygmomanometers, Electronic, Automatic, Oscillometric		
25209	Monitors, Physiologic, Vital Signs		

Other common names:
Vital signs monitoring units; noninvasive blood pressure (NIBP) monitors; auscultatory sphygmomanometers; oscillometric sphygmomanometers; oscillotonometers, spot check monitors; spot checking; Recorder, sphygmomanometer, automatic

Health problem addressed

NIBP is an essential indicator of physiologic condition. As one of the most frequently used diagnostic tests, it indicates changes in blood volume, the pumping efficiency of the heart, and the resistance of the peripheral vasculature. Vital signs monitors are used to measure basic physiologic parameters so that clinicians can be informed of changes in a patient's condition. Depending on their configuration, these units can measure and display numerical data for NIBP, oxygen saturation, and temperature.

Product description

Automatic electronic sphygmomanometers noninvasively measure and display a patient's arterial blood pressure. The main unit includes controls and a display; it also includes appropriate attached cuffs, probes, and sensors that make possible sequential and/or simultaneous measurements of the parameters. Some of the NIBP monitors can be used as vital sign monitors with the real-time measuring and display of two or more of the vital signs. These monitors typically consist of portable or mobile electronic units. The monitor may be connected to the line and/or powered by internal batteries. Many devices may also perform continuous monitoring during transportation or at the bedside. Vital signs physiologic monitors are intended mainly for periodic automated measuring of the parameters of one or more patients.

Principles of operation

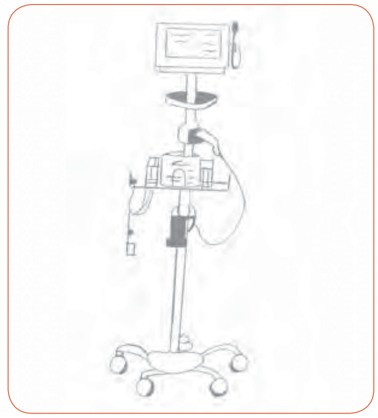
Automatic electronic sphygmomanometers (NIBP monitors) measure by the use of sound and detection of blood sound turbulence (Korotkoff sounds). A microphone positioned against an artery compressed by the device cuff detects the Korotkoff sounds, enabling the unit to directly determine systolic and diastolic values blood pressure values. NIBP is usually measured using cuffs and either auscultatory or oscillometric techniques. The measurement of temperature is typically accomplished using an intraoral sensor, and SpO2 is determined using pulse oximetry sensors. These monitors typically consist of portable or mobile electronic units that facilitate movement from one location to other; the monitor may be connected to the line and/or powered by internal batteries.

Operating steps

The cuffs, probes, and sensors are attached to the patient, and then the monitor will begin taking intermittent or continuous measurements as selected by the clinician. The devices may remain at a patient's bedside or can be transported by a caregiver for vital signs spot checking throughout a care area. Alarms (e.g., for high blood pressure or low oxygen saturation) can typically be set by caregivers and can be manually temporarily silenced.

Reported problems

Problems associated with monitors are often user-related. Poor cuff placement or sensor preparation and attachment are most commonly reported. Cables and lead wires should be periodically inspected for breaks and cracks. Automatic electronic sphygmomanometry and pulse oximeters may have the inability to effectively monitor patients with certain conditions (e.g., tremors, convulsions, abnormal heart rhythms, low blood pressure)



Use and maintenance

User(s): Physicians, nurses, other medical staff

Maintenance: Biomedical or clinical engineer/ technician, medical staff, manufacturer/ servicer

Training: Initial training by manufacturer, operator's manuals, user's guide

Environment of use

Settings of use: Hospital (all areas), ambulatory surgery centers

Requirements: Battery, uninterruptible power source, appropriate cuffs/sensors

Product specifications

Approx. dimensions (mm): 100 x 150 x 200

Approx. weight (kg): 3

Consumables: Batteries, cables, sensors/ electrodes, cuffs

Price range (USD): 580 - 4,500

Typical product life time (years): 10

Shelf life (consumables): NA

Types and variations

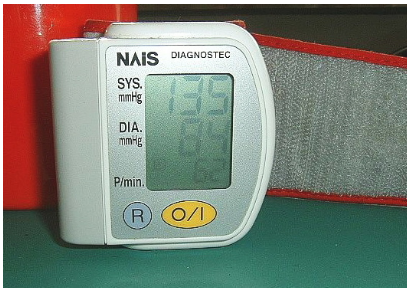
Roll stand, portable, pole or bed mounts

WHO, "Blood Pressure Monitor," From the publication: Core Medical Equipment. Geneva, Switzerland, 2011.

Blood pressure

See Hypertension for more information about high blood pressure.

Blood pressure (BP) is a force exerted by circulating blood on the walls of blood vessels, and is one of the principal vital signs. During each heartbeat, BP varies between a maximum (systolic) and a minimum (diastolic) pressure. The mean BP, due to pumping by the heart and resistance in blood vessels, decreases as the circulating blood moves away from the heart through arteries. It has its greatest decrease in the small arteries and arterioles, and continues to decrease as the blood moves through the capillaries and back to the heart through veins.[1] Gravity, valves in veins, and pumping from contraction of skeletal muscles, are some other influences on BP at various places in the body.

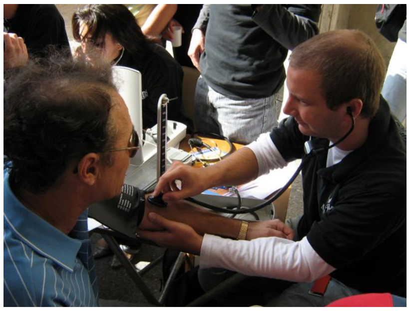


A sphygmomanometer, a device used for measuring arterial pressure.

The term *blood pressure* usually refers to the pressure measured at a person's upper arm. It is measured on the inside of an elbow at the brachial artery, which is the upper arm's major blood vessel that carries blood away from the heart. A person's BP is usually expressed in terms of the systolic pressure and diastolic pressure, for example 120/80.

Measurement

Arterial pressure is most commonly measured via a sphygmomanometer, which historically used the height of a column of mercury to reflect the circulating pressure.[2] Today BP values are still reported in millimetres of mercury (mmHg), though aneroid and electronic devices do not use mercury.



A medical student checking blood pressure using a sphygmomanometer and stethoscope.

For each heartbeat, BP varies between systolic and diastolic pressures. Systolic pressure is peak pressure in the arteries, which occurs near the end of the cardiac cycle when the ventricles are contracting. Diastolic pressure is minimum pressure in the arteries, which occurs near the beginning of the cardiac cycle when the ventricles are filled with blood. An example of normal measured values for a resting, healthy adult human is 120 mmHg systolic and 80 mmHg diastolic (written as 120/80 mmHg, and spoken [in the US] as "one-twenty over eighty").

Systolic and diastolic arterial BPs are not static but undergo natural variations from one heartbeat to another and throughout the day (in a circadian rhythm). They also change in response to stress, nutritional factors, drugs, disease, exercise, and momentarily from standing up. Sometimes the variations are large. Hypertension refers to arterial pressure being abnormally high, as opposed to hypotension, when it is abnormally low. Along with body temperature, respiratory rate, and pulse rate, BP is one of the four main vital signs routinely monitored by medical professionals and healthcare providers.[3]

Arterial pressures are usually measured non-invasively, without penetrating skin or artery. Measuring pressure invasively, by penetrating the arterial wall to take the measurement, is much less common and usually restricted to a hospital setting.

Wikipedia, "Blood Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

Noninvasive measurement

The non invasive auscultatory and oscillometric measurements are simpler and quicker than invasive measurements, require less expertise in fitting, have virtually no complications, and are less unpleasant and painful for the person. However, noninvasive methods may yield somewhat lower accuracy and small systematic differences in numerical results. Non-invasive measurement methods are more commonly used for routine examinations and monitoring.

Palpation method

A minimum systolic value can be roughly estimated without any equipment by palpation, most often used in emergency situations. Historically, students have been taught that palpation of a radial pulse indicates a minimum BP of 80 mmHg, a femoral pulse indicates at least 70 mmHg, and a carotid pulse indicates a minimum of 60 mmHg. However, at least one study indicated that this method often overestimates patients' systolic BP.[4] A more accurate value of systolic BP can be obtained with a sphygmomanometer and palpating for when a radial pulse returns.[5] The diastolic blood pressure can not be estimated by this method.[6] Sometimes palpation is used to get an estimate before using the auscultatory method.

Auscultatory method

The *auscultatory* method (from the Latin word for *listening*) uses a stethoscope and a sphygmomanometer. This comprises an inflatable (*Riva-Rocci*) cuff placed around the upper arm at roughly the same vertical height as the heart, attached to a mercury or aneroid manometer. The mercury manometer,considered the gold standard, measures the height of a column of mercury, giving an absolute result without need for calibration, and consequently not subject to the errors and drift of calibration which affect other methods. The use of mercury manometers is often required in clinical trials and for the clinical measurement of hypertension in high risk patients, such as pregnant women.

Auscultatory method aneroid sphygmomanometer with stethoscope

A cuff of appropriate size is fitted smoothly and snugly, then inflated manually by repeatedly squeezing a rubber bulb until the artery is completely occluded. Listening with the stethoscope to the brachial artery at the elbow, the examiner slowly releases the pressure in the cuff. When blood just starts to flow in the artery, the turbulent flow creates a "whooshing" or pounding (first Korotkoff sound). The pressure at which this sound is first heard is the systolic BP. The cuff pressure is further released until no sound can be heard (fifth Korotkoff sound), at the diastolic arterial pressure.

Mercury manometer

The auscultatory method has been predominant since the beginning of BP measurements but in other cases it's being replaced by other noninvasive techniques.[7]

Wikipedia, "Blood Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

Oscillometric method

The *Oscillometric* method was first demonstrated in 1876 and involves the observation of oscillations in the sphygmomanometer cuff pressure[8] which are caused by the oscillations of blood flow, i.e. the pulse.[9] The electronic version of this method is sometimes used in long-term measurements and general practice. It uses a sphygmomanometer cuff like the auscultatory method, but with an electronic pressure sensor (transducer) to observe cuff pressure oscillations, electronics to automatically interpret them, and automatic inflation and deflation of the cuff. The pressure sensor should be calibrated periodically to maintain accuracy.

Oscillometric measurement requires less skill than the auscultatory technique, and may be suitable for use by untrained staff and for automated patient home monitoring.

The cuff is inflated to a pressure initially in excess of the systolic arterial pressure, and then reduces to below diastolic pressure over a period of about 30 seconds. When blood flow is nil (cuff pressure exceeding systolic pressure) or unimpeded (cuff pressure below diastolic pressure), cuff pressure will be essentially constant. It is essential that the cuff size is correct: undersized cuffs may yield too high a pressure, whereas oversized cuffs yield too low a pressure. When blood flow is present, but restricted, the cuff pressure, which is monitored by the pressure sensor, will vary periodically in synchrony with the cyclic expansion and contraction of the brachial artery, i.e., it will oscillate. The values of systolic and diastolic pressure are computed, not actually measured from the raw data, using an algorithm; the computed results are displayed.

Oscillometric monitors may produce inaccurate readings in patients with heart and circulation problems, that include arterial sclerosis, arrhythmia, preeclampsia, pulsus alternans, and pulsus paradoxus.

In practice the different methods do not give identical results; an algorithm and experimentally obtained coefficients are used to adjust the oscillometric results to give readings which match the auscultatory results as well as possible. Some equipment uses computer-aided analysis of the instantaneous arterial pressure waveform to determine the systolic, mean, and diastolic points. Since many oscillometric devices have not been validated, caution must be given as most are not suitable in clinical and acute care settings.

The term NIBP, for Non-Invasive Blood Pressure, is often used to describe oscillometric monitoring equipment.

White-coat hypertension

For some patients, BP measurements taken in a doctor's office may not correctly characterize their typical BP.[10] In up to 25% of patients, the office measurement is higher than their typical BP. This type of error is called white-coat hypertension (WCH) and can result from anxiety related to an examination by a health care professional.[11] The misdiagnosis of hypertension for these patients can result in needless and possibly harmful medication. WCH can be reduced (but not eliminated) with automated BP measurements over 15 to 20 minutes in a quiet part of the office or clinic.[12]

Debate continues regarding the significance of this effect. Some reactive patients will also react to many other stimuli throughout their daily lives, and require treatment. In some cases a lower BP reading occurs at the doctor's office.[13]

Home monitoring

Ambulatory blood pressure devices that take readings every half hour throughout the day and night have been used for identifying and mitigating measurement problems like white-coat hypertension. Except for periods during sleep, home monitoring could be used for these purposes instead of ambulatory blood pressure monitoring.[14] Home monitoring may also be used to improve hypertension management and to monitor the effects of lifestyle changes and medication related to BP.[15] Compared to ambulatory blood pressure measurements, home monitoring has been found to be an effective and lower cost alternative.[14] [16] [17]

Aside from the white coat effect, BP readings outside of a clinical setting are usually slightly lower in the majority of people. The studies that looked into the risks from hypertension and the benefits of lowering BP in affected patients

Wikipedia, "Blood Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

were based on readings in a clinical environment.

When measuring BP, an accurate reading requires that one not drink coffee, smoke cigarettes, or engage in strenuous exercise for 30 minutes before taking the reading. A full bladder may have a small effect on BP readings, so if the urge to urinate exists, one should do so before the reading. For 5 minutes before the reading, one should sit upright in a chair with one's feet flat on the floor and with limbs uncrossed. The BP cuff should always be against bare skin, as readings taken over a shirt sleeve are less accurate. During the reading, the arm that is used should be relaxed and kept at heart level, for example by resting it on a table.[18]

Since BP varies throughout the day, measurements intended to monitor changes over longer time frames should be taken at the same time of day to ensure that the readings are comparable. Suitable times are:

- immediately after awakening (before washing/dressing and taking breakfast/drink), while the body is still resting,
- immediately after finishing work.

Automatic self-contained BP monitors are available at reasonable prices, some of which are capable of Korotkoff's measurement in addition to oscillometric methods, enabling irregular heartbeat patients to accurately measure their blood pressure at home.

Invasive measurement

Arterial blood pressure (BP) is most accurately measured invasively through an arterial line. Invasive arterial pressure measurement with intravascular cannulae involves direct measurement of arterial pressure by placing a cannula needle in an artery (usually radial, femoral, dorsalis pedis or brachial). This procedure can be done by any licensed medical doctor, nurse, or a Respiratory Therapist.

The cannula must be connected to a sterile, fluid-filled system, which is connected to an electronic pressure transducer. The advantage of this system is that pressure is constantly monitored beat-by-beat, and a waveform (a graph of pressure against time) can be displayed. This invasive technique is regularly employed in human and veterinary intensive care medicine, anesthesiology, and for research purposes.

Cannulation for invasive vascular pressure monitoring is infrequently associated with complications such as thrombosis, infection, and bleeding. Patients with invasive arterial monitoring require very close supervision, as there is a danger of severe bleeding if the line becomes disconnected. It is generally reserved for patients where rapid variations in arterial pressure are anticipated.

Invasive vascular pressure monitors are pressure monitoring systems designed to acquire pressure information for display and processing. There are a variety of invasive vascular pressure monitors for trauma, critical care, and operating room applications. These include single pressure, dual pressure, and multi-parameter (i.e. pressure / temperature). The monitors can be used for measurement and follow-up of arterial, central venous, pulmonary arterial, left atrial, right atrial, femoral arterial, umbilical venous, umbilical arterial, and intracranial pressures.

Classification

The following classification of blood pressure applies to adults aged 18 and older. It is based on the average of seated BP readings that were properly measured during 2 or more office visits.[15] [19]

Classification of blood pressure for adults

Category	systolic, mmHg	diastolic, mmHg
Hypotension	< 90	< 60
Normal	**90 – 120**	**and 60 – 80**
Prehypertension	121 – 139	or 81 – 89
Stage 1 Hypertension	140 – 159	or 90 – 99
Stage 2 Hypertension	≥ 160	or ≥ 100

Normal values

While average values for arterial pressure could be computed for any given population, there is often a large variation from person to person; arterial pressure also varies in individuals from moment to moment. Additionally, the average of any given population may have a questionable correlation with its general health, thus the relevance of such average values is equally questionable. However, in a study of 100 subjects with no known history of hypertension, an average blood pressure of 112/64 mmHg was found,[20] which is in the normal range.

Various factors influence a person's average BP and variations. Factors such as age and gender[21] influence average values. In children, the normal ranges are lower than for adults and depend on height.[22] As adults age, systolic pressure tends to rise and diastolic tends to fall.[23] In the elderly, BP tends to be above the normal adult range,[24] largely because of reduced flexibility of the arteries. Also, an individual's BP varies with exercise, emotional reactions, sleep, digestion and time of day.

Differences between left and right arm BP measurements tend to be random and average to nearly zero if enough measurements are taken. However, in a small percentage of cases there is a consistently present difference greater than 10 mmHg which may need further investigation, e.g. for obstructive arterial disease.[25] [26]

The risk of cardiovascular disease increases progressively above 115/75 mmHg.[27] In the past, hypertension was only diagnosed if secondary signs of high arterial pressure were present, along with a prolonged high systolic pressure reading over several visits. In the UK, patients' readings are considered normal up to 140/90 mmHg.[28]

Clinical trials demonstrate that people who maintain arterial pressures at the low end of these pressure ranges have much better long term cardiovascular health. The principal medical debate concerns the aggressiveness and relative value of methods used to lower pressures into this range for those who do not maintain such pressure on their own. Elevations, more commonly seen in older people, though often considered normal, are associated with increased morbidity and mortality.

Physiology

There are many physical factors that influence arterial pressure. Each of these may in turn be influenced by physiological factors, such as diet, exercise, disease, drugs or alcohol, stress, obesity, and so-forth. [29]

Some physical factors are:

- Rate of pumping. In the circulatory system, this rate is called heart rate, the rate at which blood (the fluid) is pumped by the heart. The volume of blood flow from the heart is called the cardiac output which is the heart rate (the rate of contraction) multiplied by the stroke volume (the amount of blood pumped out from the heart with each contraction). The higher the heart rate, the higher the arterial pressure, assuming no reduction in stroke volume.
- Volume of fluid or blood volume, the amount of blood that is present in the body. The more blood present in the body, the higher the rate of blood return to the heart and the resulting cardiac output. There is some relationship between dietary salt intake and increased blood volume, potentially resulting in higher arterial pressure, though

this varies with the individual and is highly dependent on autonomic nervous system response and the renin-angiotensin system.

- Resistance. In the circulatory system, this is the resistance of the blood vessels. The higher the resistance, the higher the arterial pressure upstream from the resistance to blood flow. Resistance is related to vessel radius (the larger the radius, the lower the resistance), vessel length (the longer the vessel, the higher the resistance), as well as the smoothness of the blood vessel walls. Smoothness is reduced by the build up of fatty deposits on the arterial walls. Substances called vasoconstrictors can reduce the size of blood vessels, thereby increasing BP. Vasodilators (such as nitroglycerin) increase the size of blood vessels, thereby decreasing arterial pressure. Resistance, and its relation to volumetric flow rate (Q) and pressure difference between the two ends of a vessel are described by Poiseuille's Law.
- Viscosity, or thickness of the fluid. If the blood gets thicker, the result is an increase in arterial pressure. Certain medical conditions can change the viscosity of the blood. For instance, low red blood cell concentration, anemia, reduces viscosity, whereas increased red blood cell concentration increases viscosity. Viscosity also increases with blood sugar concentration—visualize pumping syrup. It had been thought that aspirin and related "blood thinner" drugs decreased the viscosity of blood, but studies found[30] that they act by reducing the tendency of the blood to clot instead.

In practice, each individual's autonomic nervous system responds to and regulates all these interacting factors so that, although the above issues are important, the actual arterial pressure response of a given individual varies widely because of both split-second and slow-moving responses of the nervous system and end organs. These responses are very effective in changing the variables and resulting BP from moment to moment.

Mean arterial pressure

The mean arterial pressure (MAP) is the average over a cardiac cycle and is determined by the cardiac output (CO), systemic vascular resistance (SVR), and central venous pressure (CVP),[31]

$$MAP = (CO \cdot SVR) + CVP.$$

MAP can be approximately determined from measurements of the systolic pressure P_{sys} and the diastolic pressure P_{dias} while there is a normal resting heart rate,[31]

$$MAP \approxeq P_{dias} + \frac{1}{3}(P_{sys} - P_{dias}).$$

Pulse pressure

The up and down fluctuation of the arterial pressure results from the pulsatile nature of the cardiac output, i.e. the heartbeat. The pulse pressure is determined by the interaction of the stroke volume of the heart, compliance (ability to expand) of the aorta, and the resistance to flow in the arterial tree. By expanding under pressure, the aorta absorbs some of the force of the blood surge from the heart during a heartbeat. In this way the pulse pressure is reduced from what it would be if the aorta wasn't compliant.[32]

The pulse pressure can be simply calculated from the difference of the measured systolic and diastolic pressures,[32]

$$P_{pulse} = P_{sys} - P_{dias}.$$

Vascular resistance

The larger arteries, including all large enough to see without magnification, are low resistance conduits (assuming no advanced atherosclerotic changes) with high flow rates that generate only small drops in pressure.

Vascular pressure wave

Modern physiology developed the concept of the vascular pressure wave (VPW). This wave is created by the heart during the systole and originates in the ascending aorta. Much faster than the stream of blood itself, it is then transported through the vessel walls to the peripheral arteries. There the pressure wave can be palpated as the peripheral pulse. As the wave is reflected at the peripheral veins it runs back in a centripetal fashion. Where the crests of the reflected and the original wave meet, the pressure inside the vessel is higher than the true pressure in the aorta. This concept explains why the arterial pressure inside the peripheral arteries of the legs and arms is higher than the arterial pressure in the aorta,[33] [34] [35] and in turn for the higher pressures seen at the ankle compared to the arm with normal ankle brachial pressure index values.

Regulation

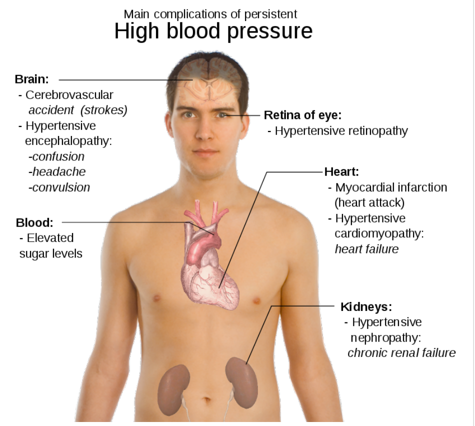
The endogenous regulation of arterial pressure is not completely understood. Currently, three mechanisms of regulating arterial pressure have been well-characterized:

- Baroreceptor reflex: Baroreceptors detect changes in arterial pressure and send signals ultimately to the medulla of the brain stem. The medulla, by way of the autonomic nervous system, adjusts the mean arterial pressure by altering both the force and speed of the heart's contractions, as well as the total peripheral resistance. The most important arterial baroreceptors are located in the left and right carotid sinuses and in the aortic arch.[36]
- Renin-angiotensin system (RAS): This system is generally known for its long-term adjustment of arterial pressure. This system allows the kidney to compensate for loss in blood volume or drops in arterial pressure by activating an endogenous vasoconstrictor known as angiotensin II.
- Aldosterone release: This steroid hormone is released from the adrenal cortex in response to angiotensin II or high serum potassium levels. Aldosterone stimulates sodium retention and potassium excretion by the kidneys. Since sodium is the main ion that determines the amount of fluid in the blood vessels by osmosis, aldosterone will increase fluid retention, and indirectly, arterial pressure.

These different mechanisms are not necessarily independent of each other, as indicated by the link between the RAS and aldosterone release. Currently, the RAS system is targeted pharmacologically by ACE inhibitors and angiotensin II receptor antagonists. The aldosterone system is directly targeted by spironolactone, an aldosterone antagonist. The fluid retention may be targeted by diuretics; the antihypertensive effect of diuretics is due to its effect on blood volume. Generally, the baroreceptor reflex is not targeted in hypertension because if blocked, individuals may suffer from orthostatic hypotension and fainting.

Pathophysiology

High arterial pressure



Overview of main complications of persistent high blood pressure.

Arterial hypertension can be an indicator of other problems and may have long-term adverse effects. Sometimes it can be an acute problem, for example hypertensive emergency.

All levels of arterial pressure put mechanical stress on the arterial walls. Higher pressures increase heart workload and progression of unhealthy tissue growth (atheroma) that develops within the walls of arteries. The higher the pressure, the more stress that is present and the more atheroma tend to progress and the heart muscle tends to thicken, enlarge and become weaker over time.

Persistent hypertension is one of the risk factors for strokes, heart attacks, heart failure and arterial aneurysms, and is the leading cause of chronic renal failure. Even moderate elevation of arterial pressure leads to shortened life expectancy. At severely high pressures, mean arterial pressures 50% or more above average, a person can expect to live no more than a few years unless appropriately treated.[37]

In the past, most attention was paid to diastolic pressure; but nowadays it is recognised that both high systolic pressure and high pulse pressure (the numerical difference between systolic and diastolic pressures) are also risk factors. In some cases, it appears that a decrease in excessive diastolic pressure can actually increase risk, due probably to the increased difference between systolic and diastolic pressures (see the article on pulse pressure).

Low arterial pressure

Blood pressure that is too low is known as hypotension. The similarity in pronunciation with *hypertension* can cause confusion. Hypotension is a medical concern only if it causes signs or symptoms, such as dizziness, fainting, or in extreme cases, shock.[19]

When arterial pressure and blood flow decrease beyond a certain point, the perfusion of the brain becomes critically decreased (i.e., the blood supply is not sufficient), causing lightheadedness, dizziness, weakness or fainting.

Sometimes the arterial pressure drops significantly when a patient stands up from sitting. This is known as orthostatic hypotension (postural hypotension); gravity reduces the rate of blood return from the body veins below the heart back to the heart, thus reducing stroke volume and cardiac output.

When people are healthy, the veins below their heart quickly constrict and the heart rate increases to minimize and compensate for the gravity effect. This is carried out involuntarily by the autonomic nervous system. The system usually requires a few seconds to fully adjust and if the compensations are too slow or inadequate, the individual will suffer reduced blood flow to the brain, dizziness and potential blackout. Increases in G-loading, such as routinely experienced by aerobatic or combat pilots 'pulling Gs', greatly increases this effect. Repositioning the body perpendicular to gravity largely eliminates the problem.

Other causes of low arterial pressure include:

- Sepsis
- Hemorrhage - blood loss
- Toxins including toxic doses of BP medicine
- Hormonal abnormalities, such as Addison's disease

Shock is a complex condition which leads to critically decreased perfusion. The usual mechanisms are loss of blood volume, pooling of blood within the veins reducing adequate return to the heart and/or low effective heart pumping. Low arterial pressure, especially low pulse pressure, is a sign of shock and contributes to and reflects decreased perfusion.

If there is a significant difference in the pressure from one arm to the other, that may indicate a narrowing (for example, due to aortic coarctation, aortic dissection, thrombosis or embolism) of an artery.

Other sites

Blood pressure generally refers to the arterial pressure in the systemic circulation. However, measurement of pressures in the venous system and the pulmonary vessels plays an important role in intensive care medicine but requires an invasive central venous catheter.

Venous pressure

Venous pressure is the vascular pressure in a vein or in the atria of the heart. It is much less than arterial pressure, with common values of 5 mmHg in the right atrium and 8 mmHg in the left atrium.

Pulmonary pressure

Normally, the pressure in the pulmonary artery is about 15 mmHg at rest.[38]

Increased BP in the capillaries of the lung cause pulmonary hypertension, with interstitial edema if the pressure increases to above 20 mmHg, and to frank pulmonary edema at pressures above 25 mmHg.[39]

Fetal blood pressure

In pregnancy, it is the fetal heart and not the mother's heart that builds up the fetal BP to drive its blood through the fetal circulation.

The BP in the fetal aorta is approximately 30 mmHg at 20 weeks of gestation, and increases to ca 45 mmHg at 40 weeks of gestation.[40]
The average BP for full-term infants:
Systolic 65–95 mm Hg
Diastolic 30–60 mm Hg [41]

See also

- Ambulatory blood pressure
- Antihypertensive
- Auscultatory gap
- Central venous pressure
- Hypertension
- Hypotension
- Korotkoff sounds
- Lactotripeptides
- Mean arterial pressure
- Prehypertension
- Pulse pressure
- Pulse rate
- Resperate
- Sphygmomanometer

- Vital signs

References

1. Pickering, TG; Hall, JE; Appel, LJ *et al*. (2005). "Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research" [42]. *Hypertension* **45** (5): 142–61. doi:10.1161/01.HYP.0000150859.47929.8e. PMID 15611362. Retrieved 2009-10-01.

External links

- High Blood Pressure [43], The Institute for Good Medicine [44] at the Pennsylvania Medical Society [45]
- Blood Pressure Association (UK) [46]
- British Hypertension Society: list of validated blood pressure monitors [47]
- Blood pressure monitoring [48]
- Pulmonary Hypertension [49] Cleveland Clinic
- Blood Pressure Calculator for Diagnosis of High blood pressure in Children and Adolescents [50]
- dablEducational Trust: Blood pressure monitors - Validations, Papers, and Reviews [51]
- American Heart Association[52]

References

[1] Klabunde, Richard (2005). *Cardiovascular Physiology Concepts*. Lippincott Williams & Wilkins. pp. 93–4. ISBN 978-0781750301.

[2] Booth, J (1977). "A short history of blood pressure measurement" (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1543468). *Proceedings of the Royal Society of Medicine* **70** (11): 793–9. PMID 341169. PMID 341169. PMC 1543468. . Retrieved 2009-10-06.

[3] "Vital Signs (Body Temperature, Pulse Rate, Respiration Rate, Blood Pressure)" (http://www.ohsu.edu/xd/health/health-information/topic-by-id.cfm?ContentTypeId=85&ContentId=P00866). *OHSU Health Information*. Oregon Health & Science University. . Retrieved 2010-04-16.

[4] Deakin CD, Low JL (September 2000). "Accuracy of the advanced trauma life support guidelines for predicting systolic blood pressure using carotid, femoral, and radial pulses: observational study" (http://bmj.com/cgi/pmidlookup?view=long&pmid=10987771). *BMJ* **321** (7262): 673–4. doi:10.1136/bmj.321.7262.673. PMID 10987771. PMC 27481. .

[5] Interpretation - Blood Pressure - Vitals (http://bcs.medinfo.ufl.edu/sample/page06.html), "University of Florida". Retrieved on 2008-03-18.

[6] G8 Secondary Survey (http://www.gov.mb.ca/health/ems/guidelines/G8.pdf), "Manitoba". Retrieved on 2008-03-18.

[7] (Pickering et al. 2005, p. 146) See *Blood Pressure Measurement Methods*.

[8] (Pickering et al. 2005, p. 147) See *The Oscillometric Technique*.

[9] Laurent, P (2003-09-28). "Blood Pressure & Hypertension" (http://www.blood-pressure-hypertension.com/how-to-measure/measure-blood-pressure-8.shtml). . Retrieved 2009-10-05.

[10] Elliot, Victoria Stagg (2007-06-11). "Blood pressure readings often unreliable" (http://www.ama-assn.org/amednews/2007/06/11/hlsa0611.htm). *American Medical News* (American Medical Association). . Retrieved 2008-08-16.

[11] Jhalani, Juhee; Tanya Goyal, Lynn Clemow, et al (2005). "Anxiety and outcome expectations predict the white-coat effect" (http://journals.lww.com/bpmonitoring/pages/articleviewer.aspx?year=2005&issue=12000&article=00006&type=abstract). *Blood Pressure Monitoring* **10** (6): 317–9. doi:10.1097/00126097-200512000-00006. PMID 16496447. PMID 16496447. . Retrieved 2009-10-03.

[12] (Pickering et al. 2005, p. 145) See *White Coat Hypertension or Isolated Office Hypertension*.

[13] (Pickering et al. 2005, p. 146) See *Masked Hypertension or Isolated Ambulatory Hypertension*.

[14] Mancia G, De Backer G, Dominiczak A, et al (June 2007). "2007 Guidelines for the management of arterial hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC)". *Eur Heart J* **28** (12): 1462–536. doi:10.1093/eurheartj/ehm236. PMID 17562668.

[15] Chobanian AV, Bakris GL, Black HR, *et al* (December 2003). "Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure" (http://www.nhlbi.nih.gov/guidelines/hypertension/). *Hypertension* **42** (6): 1206–52. doi:10.1161/01.HYP.0000107251.49515.c2. PMID 14656957. .

[16] Niiranen, TJ; Kantola IM, Vesalainen R, et al (2006). "A comparison of home measurement and ambulatory monitoring of blood pressure in the adjustment of antihypertensive treatment". *Am J Hypertens* **19** (5): 468–74. doi:10.1016/j.amjhyper.2005.10.017. PMID 16647616.

[17] Shimbo, Daichi; Thomas G. Pickering, Tanya M. Spruill, et al (2007). "Relative utility of home, ambulatory, and office blood pressures in the prediction of end-organ damage" (http://www.nature.com/ajh/journal/v20/n5/abs/ajh200783a.html). *Am J Hypertens* **20** (5): 476–82. doi:10.1016/j.amjhyper.2006.12.011. PMID 17485006. PMC 1931502. .
[18] National Heart, Lung and Blood Institute. *Tips for having your blood pressure taken* (http://www.nhlbi.nih.gov/hbp/detect/tips.htm). .
[19] "Diseases and Conditions Index - Hypotension" (http://www.nhlbi.nih.gov/health/dci/Diseases/hyp/hyp_whatis.html). National Heart Lung and Blood Institute. September 2008. . Retrieved 2008-09-16.
[20] Pesola GR, Pesola HR, Nelson MJ, Westfal RE (January 2001). "The normal difference in bilateral indirect BP recordings in normotensive individuals" (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6W9K-45SRDHC-C&_user=10&_coverDate=01/31/2001&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=74f2b32e088d88986cd307f6c7219331). *Am J Emerg Med* **19** (1): 43–5. doi:10.1053/ajem.2001.20021. PMID 11146017. .
[21] Reckelhoff, Jane F. (1 May 2001). "Gender Differences in the Regulation of Blood Pressure" (http://hyper.ahajournals.org/cgi/content/abstract/hypertensionaha;37/5/1199). *Hypertension* **37** (5): 1199–208. PMID 11358929. PMID 11358929. .
[22] National Heart, Lung and Blood Institute. *Blood Pressure Tables for Children and Adolescents* (http://www.nhlbi.nih.gov/guidelines/hypertension/child_tbl.htm). . (Note that the median BP is given by the 50th percentile and hypertension is defined by the 95th percentile for a given age, height, and gender.)
[23] (Pickering et al. 2005, p. 145) See *Isolated Systolic Hypertension*.
[24] "...more than half of all Americans aged 65 or older have hypertension." (Pickering et al. 2005, p. 144)
[25] Eguchi K, Yacoub M, Jhalani J, Gerin W, Schwartz JE, Pickering TG (February 2007). "Consistency of blood pressure differences between the left and right arms" (http://archinte.ama-assn.org/cgi/content/full/167/4/388). *Arch Intern Med* **167** (4): 388–93. doi:10.1001/archinte.167.4.388. PMID 17325301. .
[26] Agarwal R, Bunaye Z, Bekele DM (March 2008). "Prognostic significance of between-arm blood pressure differences". *Hypertension* **51** (3): 657–62. doi:10.1161/HYPERTENSIONAHA.107.104943. PMID 18212263.
[27] Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM (February 2006). "Dietary approaches to prevent and treat hypertension: a scientific statement from the American Heart Association". *Hypertension* **47** (2): 296–308. doi:10.1161/01.HYP.0000202568.01167.B6. PMID 16434724.
[28] "Hypertension: management of hypertension in adults in primary care" (http://www.nice.org.uk/nicemedia/pdf/CG034NICEguideline.pdf). *NICE Clinical Guideline 34*. London, England: National Institute for Health and Clinical Excellence (NICE). June 2006. . Retrieved 2008-09-15.
[29] (http://www.americanheart.org/presenter.jhtml?identifier=4650)
[30] Rosenson RS, Wolff D, Green D, Boss AH, Kensey KR (February 2004). "Aspirin. Aspirin does not alter native blood viscosity". *J. Thromb. Haemost.* **2** (2): 340–1. PMID 14996003.
[31] Klabunde, RE (2007). "Cardiovascular Physiology Concepts - Mean Arterial Pressure" (http://www.cvphysiology.com/Blood Pressure/BP006.htm). . Retrieved 2008-09-29. Archived version 2009-10-03 (http://www.webcitation.org/5kGLMdqnn)
[32] Klabunde, RE (2007). "Cardiovascular Physiology Concepts - Pulse Pressure" (http://www.cvphysiology.com/Blood Pressure/BP003.htm). . Retrieved 2008-10-02. Archived version 2009-10-03 (http://www.webcitation.org/5kGLuC47S)
[33] Messerli FH, Williams B, Ritz E (2007). "Essential hypertension". *Lancet* **370** (9587): 591–603. doi:10.1016/S0140-6736(07)61299-9. PMID 17707755.
[34] O'Rourke M (1 July 1995). "Mechanical principles in arterial disease" (http://hyper.ahajournals.org/cgi/content/full/26/1/2). *Hypertension* **26** (1): 2–9. PMID 7607724. .
[35] Mitchell GF (2006). "Triangulating the peaks of arterial pressure" (http://hyper.ahajournals.org/cgi/content/full/48/4/543). *Hypertension* **48** (4): 543–5. doi:10.1161/01.HYP.0000238325.41764.41. PMID 16940226. .
[36] Klabunde, RE (2007). "Cardiovascular Physiology Concepts - Arterial Baroreceptors" (http://www.cvphysiology.com/Blood Pressure/BP012.htm). . Retrieved 2008-09-09.
[37] Textbook of Medical Physiology, 7th Ed., Guyton & Hall, Elsevier-Saunders, ISBN 0-7216-0240-1, page 220.
[38] What Is Pulmonary Hypertension? (http://www.nhlbi.nih.gov/health/dci/Diseases/pah/pah_what.html) From Diseases and Conditions Index (DCI). National Heart, Lung, and Blood Institute. Last updated September 2008. Retrieved on 6 April, 2009.
[39] Chapter 41, page 210 in: Cardiology secrets (http://books.google.com/books?id=IYFAsxAUA_MC&printsec=frontcover#PPR3,M1) By Olivia Vynn Adair Edition: 2, illustrated Published by Elsevier Health Sciences, 2001 ISBN 1560534206, 9781560534204
[40] Struijk PC, Mathews VJ, Loupas T, *et al* (October 2008). "Blood pressure estimation in the human fetal descending aorta". *Ultrasound Obstet Gynecol* **32** (5): 673–81. doi:10.1002/uog.6137. PMID 18816497.
[41] Sharon, S. M. & Emily, S. M.(2006). *Fundations of Maternal-Newborn Nursing.* (4th ed p.476). Philadelphia:Elsevier.
[42] http://hyper.ahajournals.org/cgi/content/full/45/1/142
[43] http://www.myfamilywellness.org/MainMenuCategories/FamilyHealthCenter/Heart/Hypertension.aspx
[44] http://www.goodmedicine.org
[45] http://www.pamedsoc.org
[46] http://www.bpassoc.org.uk
[47] http://www.davidgregory.org/blood_pressure_monitors.htm
[48] http://www.blood-pressure-monitoring.org
[49] http://www.clevelandclinicmeded.com/medicalpubs/diseasemanagement/nephrology/arterial-hypertension/

Wikipedia, "Blood Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

[50] http://www.etoolsage.com/Calculator/Blood_Pressure_Calculator.asp?toolsort=1500
[51] http://www.dableducational.org/
[52] http://www.americanheart.org/presenter.jhtml?identifier=4650

Article Sources and Contributors

Blood pressure *Source*: http://en.wikipedia.org/w/index.php?oldid=358960691 *Contributors*: 4wajzkd02, 5-HT8, 5Q5, A8UDI, Abdmy011, Abeg92, Abrech, Aceofhearts1968, Adam Zivner, Addshore, Aitias, Ajh16, Ale jrb, Alex.tan, Alexius08, Algumacoisaqq, Ali, Andre Engels, AndrewHowse, AndrewWTaylor, Anfieldroad, Angus Lepper, Anim8cme, Ann Stouter, Anna Lincoln, Antonio Lopez, Arakunem, Arcadian, Arch dude, Arjun01, Ashishbhatnagar72, Assume5, AxelBoldt, B. Wolterding, Barek, Beano, Bear and Dragon, Beetstra, Bemoeial, Bencherlite, Bensaccount, Bfesser, BillC, Biyer, BlaiseFEgan, Blood Pressure Association Publications Officer, Blue Tie, Bob K31416, BobKawanaka, Bobo192, Brandon, Brendan Moody, Brighterorange, Bubba hotep, Buchskj, Burlywood, Butwhatdoiknow, Bücherwürmlein, CIreland, Can't sleep, clown will eat me, Canihaveacookie, CanuckViking, CapitalR, Cburnett, Ccacsmss, Celarnor, Chamal N, Charles Gaudette, Chowbok, Chuckmoran7, Closedmouth, CoJaBo, Colenso, Cometstyles, Correogsk, Crystallina, Csdorman, DFS454, DMacks, DRosenbach, DVD R W, Da monster under your bed, Dan Gluck, Daniel.Cardenas, Dank, Darth Panda, David Henderson, DavidSmith8888, Davidoff, Davidruben, DeadEyeArrow, December21st2012Freak, Defender of torch, Deli nk, Delldot, Deor, DerHexer, Diberri, Dionysia, Djgregory, Djk3, Dlohcierekim, Docu, Dog Eat Dog World, Dominus, Doops, Dovid, DrMacrophage, Dreamyshade, Drum guy, Dwinner, E Wing, E rulez, Edgar181, Eekerz, EhJJ, Eiler7, Ekko, ElKevbo, Eliazar, Emote, Emperorbma, Epbr123, Eric-Wester, Erik9, Fabrício Kury, Facts707, Faradayplank, FisherQueen, Flewis, FlyingToaster, Fnielsen, Founders4, Fredrik, FreplySpang, Frmatt, Fulkkari, G0dsweed, Gabbe, Gene Nygaard, GermanX, Giftlite, Gilliam, Gizz, Gogo Dodo, GordonMarjory, Grubber, HTGuru, Hadal, Haham hanuka, HappyInGeneral, Harej, Healy24, Heimoma, Heron, Hiberniantears, Holdspa, Hooperbloob, HorsePunchKid, Hu12, Hut 8.5, IW.HG, Ice Cold Beer, Iridescent, Isidore, J Di, J.delanoy, J04n, JForget, JHP, Jack-A-Roe, Jackhynes, Jacqui M, James086, JamesAM, Jared Hunt, Jasonkodat, Jecowa, Jeff Silvers, Jeffq, Jeremygbyrne, Jfdwolff, JimmyAndRobert!, Jimp, Jkgray, Jmarchn, Jmh649, Jmor7, John Kaduwanema, JohnCub, Johnduffell, Jojhutton, Jonathunder, Jonny-mt, Jorvik, Joyous!, Jprey, JuliaHavey, JulieADriver, Julo, Justinstroud, Kansas Sam, Karlhahn, Kartano, Kelliel@iinet.net.au, Kevino62, Kilbosh, King of Hearts, Kitty bean, Klausness, Knowledge Seeker, Kosebamse, Ksheka, Kukini, Kylet, Kyoko, LAX, Lactotripeptide, LeadSongDog, LeaveSleaves, Lexicontra, Lheydon, LimpThis, LittleDan, Lkinkade, Lmuenchen, LordRae, Losmog, Luk, Lupinoid, M1ss1ontomars2k4, MAlvis, MER-C, MONGO, Macaddct1984, Maderchoud334, Maderchoudsala44, Madhero88, Magioladitis, Marek69, MarkSutton, Martin451, Master Jay, Masterchiefthespartan117, Matt povey, Me, MeVsAll, Mentifisto, Merube 89, Mfranck, Michael V Hayes, Mig174, Mikael Häggström, Mike Magowan, Mike Rosoft, Miranda, Mootros, Mr Goulash, Mrdocjb, Muchclag, Myadav, Mzcrazybitch, N-k, Naniwako, Nastajus, Natkeeran, Nehrams2020, Neptune5000, Nfu-peng, Nick C, Nicnic m, Nikzbitz, Nmg20, Notepadpage, Nutcrakerr, Ocdcntx, Ohnoitsjamie, Okedem, Olorin28, Onevalefan, Orangedwarf, OrgasGirl, Osbus, Oxymoron83, Paiamshadi, Pandaassassin7, Patrick, PatronSaintOfEntropy, Peruvianllama, PeteThePill, Phansen, Phgao, Phil Wardle, Philip Trueman, Piano non troppo, Pilarian, Pinethicket, Piplicus, Pol098, Polacrilex, PreThinker, Prodego, Puffball, Quaint and curious, RDBrown, RNchoo, Rajah, Rdsmith4, Remi0o, Renato Caniatti, Res2216firestar, RexNL, Rich Farmbrough, Rjwilmsi, Rob Hooft, Roberta F., Romanm, Ronz, RoyBoy, Rsduhamel, Ryancormack, Ryguasu, SJP, SMC, Sampi, Sango123, Scarian, Scohoust, Selket, Septine, Seuwin, Shanes, Sho Uemura, Sinkker, Sjakkalle, Skarebo, Sljaxon, Snowmanradio, Someone else, Sonett72, Spiff666, Spongefrog, SportWagon, SqueakBox, SstrykerR, Stack, Statkit1, Stephen, Steven Zhang, Stevenfruitsmaak, Supten, Surturz, Svadhisthana, TSoprano, Tarquin, TastyPoutine, Tempodivalse, TexasAndroid, The Rambling Man, The Thing That Should Not Be, TheEgyptian, TheNewPhobia, Thumperward, Tide rolls, TigerShark, Tkessler, Todd Vierling, Tom Yates, Toreau, Tpaba, Tresiden, Troop350, TruthIsStrangerThanFiction, Tsujigiri, UISKuwait, Uknowme imbehindu, Ulric1313, Uncle Bill, User38934, Uthbrian, Utopianheaven, V.narsikar, Van helsing, Vary, VasilievVV, WDM27, WadeSimMiser, Wap, Wayunga, Wayward, Westendgirl, WhatamIdoing, Wikiperson0202, Wimt, Wisdom89, Wouterstomp, Wraithdart, Xlegiofalco, Yidisheryid, Yintan, Ymaziar, Yoweigh, Yuanchosaan, Zephalis, Zuff, Zzuuzz, محبوب عالم, 983 anonymous edits

Image Sources, Licenses and Contributors

Image:Blutdruck.jpg *Source*: http://en.wikipedia.org/w/index.php?title=File:Blutdruck.jpg *License*: GNU Free Documentation License *Contributors*: User:Peng

Image:MMSA Checking Blood Pressure.JPG *Source*: http://en.wikipedia.org/w/index.php?title=File:MMSA_Checking_Blood_Pressure.JPG *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: Kilbosh

Image:Sphygmomanometer.jpg *Source*: http://en.wikipedia.org/w/index.php?title=File:Sphygmomanometer.jpg *License*: Public Domain *Contributors*: BrokenSphere, Edward, EugeneZelenko, GreyCat, Ranveig, Saperaud

Image:Mercury manometer.jpg *Source*: http://en.wikipedia.org/w/index.php?title=File:Mercury_manometer.jpg *License*: GNU Free Documentation License *Contributors*: Original uploader was Michael V Hayes at en.wikipedia

File:Main complications of persistent high blood pressure.svg *Source*: http://en.wikipedia.org/w/index.php?title=File:Main_complications_of_persistent_high_blood_pressure.svg *License*: Public Domain *Contributors*: Mikael Häggström

License

Wikipedia, "Blood Pressure." Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

Pulse pressure

Pulse pressure is the difference between systolic and diastolic blood pressure, or the change in blood pressure seen during a contraction of the heart.

Calculation

Formally it is the **systolic pressure minus the diastolic pressure.**[1]

Theoretically, the systemic pulse pressure can be conceptualized as being proportional to stroke volume and inversely proportional to the compliance of the aorta[2] .

- Systemic pulse pressure = $P_{systolic}$ - $P_{diastolic}$ = 120mmHg - 80mmHg = 40mmHg
- Pulmonary pulse pressure = $P_{systolic}$ - $P_{diastolic}$ = 25mmHg - 10mmHg = 15mmHg

Values and variation

Low values

In trauma a low or narrow pulse pressure suggests significant blood loss.[3] In an otherwise healthy person a difference of less than 40 mmHg is usually an error of measurement. If the pulse pressure is genuinely low, e.g. 25 mmHg or less, the cause may be low stroke volume, as in Congestive Heart Failure and/or shock, a serious issue. This interpretation is reinforced if the resting heart rate is relatively rapid, e.g. 100-120 (in sinus tachycardia), reflecting increased sympathetic nervous system activity as the body's response to low stroke volume and low cardiac output. A narrow pulse pressure can also be caused by aortic stenosis.

Examples: (these are examples of WIDENING pulse pressure causes)

- Atherosclerosis
- Chronic aortic regurgitation
- Thyrotoxicosis
- Fever
- Anaemia
- Pregnancy
- Anxiety
- Heart block
- Aortic dissection
- Endocarditis
- Raised intracranial pressure

High values during or shortly after exercise

Usually, the resting pulse pressure in healthy adults, sitting position, is about 40 mmHg. The pulse pressure increases with exercise due to increased stroke volume[4] , healthy values being up to pulse pressures of about 100 mmHg, simultaneously as total peripheral resistance drops during exercise. In healthy individuals the pulse pressure will typically return to normal within about 10 minutes. For most individuals, during exercise, the systolic pressure progressively increases while the diastolic remains about the same. In some very aerobically athletic individuals, for example distance runners, the diastolic will progressively fall as the systolic increases. This behavior facilitates a much greater increase in stroke volume and cardiac output at a lower mean arterial pressure and enables much greater aerobic capacity and physical performance. The diastolic drop reflects a much greater fall in total peripheral resistance of the muscle arterioles in response to the exercise (a greater proportion of red versus white muscle tissue). Individuals with larger BMI's due to increased muscle mass (body builders) have also been shown to have lower diastolic pressures and larger pulse pressures.[5]

Consistently high values

If the usual resting pulse pressure is consistently greater than 40 mmHg, e.g. 60 or 80 mmHg, the most likely basis is stiffness of the major arteries, aortic regurgitation (a leak in the aortic valve), arteriovenous malformation (an extra path for blood to travel from a high pressure artery to a low pressure vein without the gradient of a capillary bed), hyperthyroidism or some combination. (A chronically increased stroke volume is also a technical possibility, but very rare in practice.) While some drugs for hypertension have the side effect of increasing resting pulse pressure irreversibly, other hypertension drugs, such as ACE Inhibitors, have been shown to lower pulse pressure. A high resting pulse pressure is harmful and tends to accelerate the normal aging of body organs, particularly the heart, the brain and kidneys. A high pulse pressure combined with bradycardia is associated with increased intracranial pressure and should be reported to a physician immediately.

Relationship to heart disease

Recent work suggests that a high pulse pressure is an important risk factor for heart disease. A meta-analysis in 2000, which combined the results of several studies of 8,000 elderly patients in all, found that a 10 mm Hg increase in pulse pressure increased the risk of major cardiovascular complications and mortality by nearly 20%.[6] Heightened pulse pressure is also a risk factor for the development of atrial fibrillation.[7] The authors of the meta-analysis suggest that this helps to explain the apparent increase in risk sometimes associated with low diastolic pressure, and warn that some medications for high blood pressure may actually increase the pulse pressure and the risk of heart disease.

Self measurement

Pulse pressure readings can be taken on a home monitoring blood pressure device. Most home monitoring blood pressure devices display systolic and diastolic blood pressure and pulse pressure readings. Monitoring at home will measure true pulse and blood pressure and provide a doctor with a log of readings over time.

Treatment

If the patient suffers from elevated pulse pressure, treatment should include medication that addresses this factor, such as an angiotensin-converting enzyme inhibitor (ACE inhibitor).[8]

Effect of folic acid

A 2005 study found that 5 mg of folate daily over a three-week period reduced pulse pressure by 4.7 mm of Hg compared with a placebo, and concluded that Folic acid is an effective supplement that targets large artery stiffness and may prevent isolated systolic hypertension.[9]

See also

- Blood pressure
- Mean arterial pressure
- Cold pressor test
- Hypertension
- Prehypertension
- Antihypertensive
- Patent ductus arteriosus

References

[1] http://wiki.answers.com/Q/Why_is_mean_arterial_pressure_not_equal_to_systolic_pressure_minus_diastolic_pressure_dived_by_2

[2] Arterial pulse pressure (http://www.cvphysiology.com/Blood Pressure/BP003.htm)

[3] American College of Surgeons (2008). *Atls, Advanced Trauma Life Support Program for Doctors*. Amer College of Surgeons. pp. 58. ISBN 1-880696-31-6.

[4] (http://www.pps.org.pk/PJP/3-2/07-Farida.pdf)

[5] (http://hyper.ahajournals.org/cgi/content/full/33/6/1385?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&fulltext=arterial&searchid=1&FIRSTINDEX=60&resourcetype=HWFIG)

[6] Blacher J, Staessen JA, Girerd X, Gasowski J, Thijs L, Liu L, Wang JG, Fagard RH, Safar ME. Pulse pressure not mean pressure determines cardiovascular risk in older hypertensive patients. *Arch Intern Med* 2000 Apr 24;160(8):1085-9. PMID 10789600

[7] Pulse Pressure Important Risk Factor for the Development of New-Onset AF CME http://www.medscape.com/viewarticle/552468

[8] Pulse Pressure Builds Steam as Mortality Predictor - Brief Article - Statistical Data Included http://findarticles.com/p/articles/mi_m0BJI/is_1_30/ai_59457655

hypertensive patients with high pulse pressures should include a drug that is effective at reducing pulse pressure, and angiotensin-converting enzyme inhibitors are the best for this purpose.

[9] Carolyn Williams, Bronwyn A Kingwell, Kevin Burke, Jane McPherson and Anthony M Dart: Folic acid supplementation for 3 wk reduces pulse pressure and large artery stiffness independent of MTHFR genotype. American Journal of Clinical Nutrition, Vol. 82, No. 1, 26-31, July 2005 http://www.ajcn.org/cgi/content/full/82/1/26

Article Sources and Contributors

Pulse pressure *Source*: http://en.wikipedia.org/w/index.php?oldid=353873668 *Contributors*: 1ForTheMoney, Aesopos, Agentdenim, Anespa, Arcadian, Brummfuss, D6, Dpen2000, Dreamyshade, Epbr123, Fibrosis, Fredrik, Frycow, Goodnightmush, Jfdwolff, Jmbigwood, Jmh649, John254, Ksheka, Ladida, Luna Santin, MAlvis, MastCell, Monitorer, Nodekeeper, Notepadpage, Orlandoturner, Pol098, Prisonblues, Ptdecker, Ryanjc559, ShakingSpirit, Thorwald, Topgunner, Woohookitty, 55 anonymous edits

License

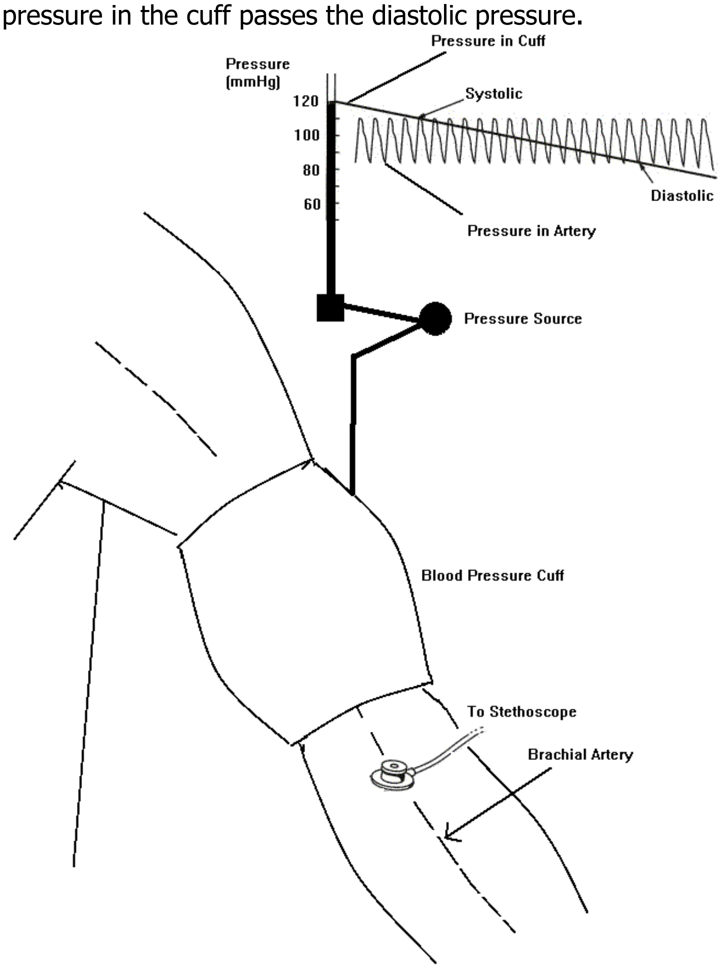
Operation and Use of Blood Pressure Monitors

2.6 Blood Pressure Machines

2.6.1 Clinical Use and Principles of Operation

Blood pressure machines are one of the primary diagnostic tools used by health care workers. Sphygmomanometers are used for determining the patient's resting blood pressure, one of the preliminary tests that health care workers may perform. A diagnosis of high or low blood pressure can be indicative of other, more serious diseases. There are three main types of blood pressure machines: mercury, aneroid, and electronic.

The measurement of blood pressure has been common for over a century and is often misunderstood. The non-invasive measurement of blood pressure is accomplished by occluding an artery in the upper arm with an inflatable cuff that is connected to a mercury manometer. A stethoscope is used to listen for the Korotkoff's sounds as the blood flows. The first sound is heard as the pressure in the cuff passes the systolic pressure. The last sound is heard as the pressure in the cuff passes the diastolic pressure.



A traditional blood pressure measurement is made by occluding the brachial artery with a cuff. As the cuff is deflated, the technician can hear, at first, nothing, as no blood flows in the artery, then a sound as the pressure in the cuff is just below the systolic (maximum) pressure. When the cuff pressure just descends below the diastolic (minimum) pressure, the sound goes away because the flow returns to laminar flow.

The ideal pressure is 120 mmHg systolic and 80 mmHg diastolic. Systolic pressures above 150 mmHg or diastolic pressures above 100 mmHg are of clinical concern. The difference between the systolic and diastolic pressures is called the pulse pressure. This generally runs between 40

Malkin, R. "Blood Pressure Machines," From the publication: Medical Instruments in the Developing World. Engineering World Health, 2006.

and 50 mmHg. An estimated mean pressure can be obtained by adding one third of the pulse pressure to the diastolic pressure. The mean pressure shouldn't drop below about 80 mmHg.

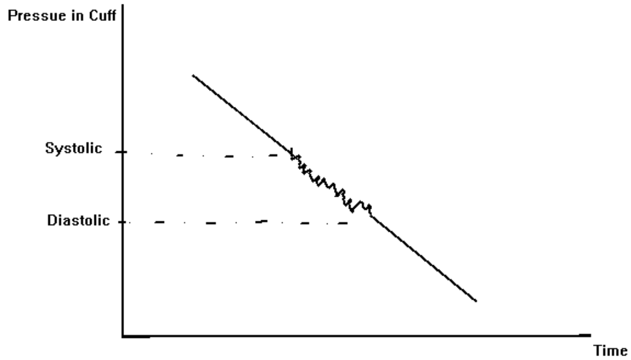
To measure the pressure in the cuff, a mercury manometer is often used. A plastic or glass column with graduations from 0 to 300 mm is connected to the cuff via latex or rubber tubing. The tube is filled with mercury. The pressure reading is the height of the mercury column. To get accurate readings the tube must be exactly vertical. At the top of the tube, under the cap is a calf skin diaphragm that allows air to move in both directions. If this diaphragm is dirty the mercury in the column will not move smoothly, either up or down. Mercury manometers are no longer used in The United States. However, they are quite common in the developing world.

In this photo, the cover for the mercury reservoir has been removed (right). The mercury has oxidized leaving a fine powder that should be removed before refilling the reservoir.

Another manometer used for blood pressure readings is the aneroid manometer. This is a bellows based system that has a dial calibrated in the range of 0 to 300 mmHg. At the resting point of the needle on the dial is a rectangular box. If the needle is in that box the manometer is calibrated and can be used.

An aneroid manometer uses a calibrated dial. Notice that when the dial is at zero, there is a small rectangle where the needle should rest. This manometer is also calibrated in inches of water.

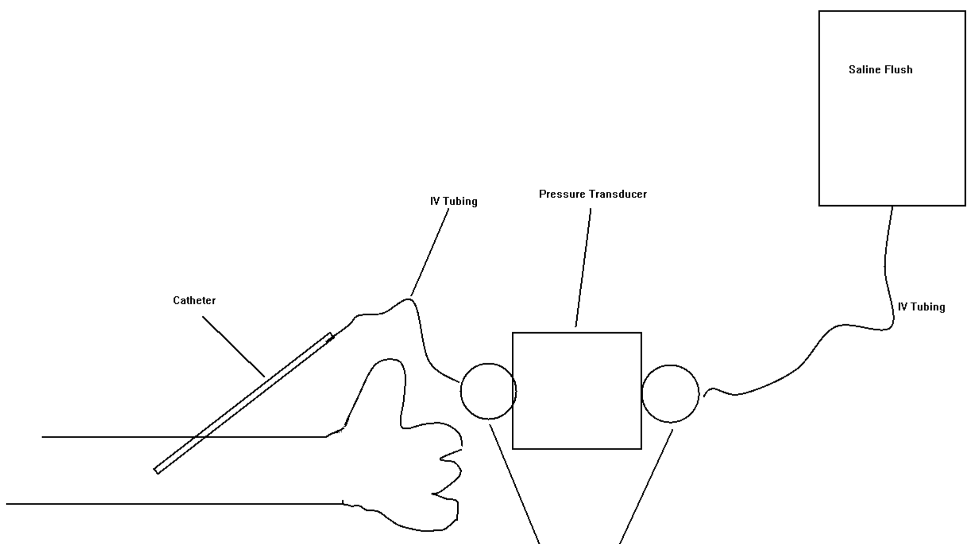
Non-invasive blood pressure machines (NIBP) are devices that automatically and electronically measure blood pressure. In these system electronics replaces a human in the inflation/deflation of the cuff. In most modern devices, the detection of the pulsation, not the listening for Korotkoff sounds, drives the detection of the maximum and minimum pressure. The results are displayed in digital format on separate displays or on a screen. The units can be programmed to take blood pressures on a set cycle, 1, 5, 15, 30 minutes, trend the data and often sound alarms if the results are outside of preset limits.



Automatic non-invasive blood pressure (NIBP) machines typically measure the presence of small oscillations in the pressure to determine the systolic and diastolic pressures. Some older machines may use a sensor to detect the Korotkoff sounds.

Older NIBP's may use two tubes to inflate the blood pressure cuff. Some devices have a transducer in the cuff to detect the sounds.

A completely different approach to measuring blood pressure is to invasively introduce a catheter into an artery. This is most common in surgery and intensive care units. The blood pressure device is connected to the catheter via a rigid wall plastic tube filled with a saline solution. The tube is connected to a transducer, which may be connected to bag of saline or "flush." Figure 2.7.3 illustrates the set up. The transducer is hung at the level of the heart. The output from the transducer is amplified and displayed as numbers, waveform or both. Since the skin has been breached the patients first line of defense for both infection and electrical shock have been bypassed. Extreme care must be taken to assure the safety of the patient.



An invasive blood pressure measurement typically involves piercing the skin of the arm or leg. The pressure transducer should always be at the level of the patient's heart. The flush bag is held a foot or more above the patient.

2.6.2 Common Problems

Non-invasive, manual blood pressure machines are extremely reliable. They are also inexpensive. Even in the developing world, they are often replaced rather than repaired. However, there are a few common problems.

Leaks in the tubing are common and can often be repaired with epoxy or silastic. To check for leaks, inflate the cuff to 250 mmHg and allow it to stand. The pressure should slowly decrease at a rate not exceeding 5 mmHg per minute. If there is a leak, you can find it by rubbing soapy water over the tubing and looking for bubbles.

User errors related to calibration are somewhat common. The cuff must be at the level of the heart and the manometer must read zero before the cuff is inflated. Check the cleanliness of the mercury. After a time, mercuric oxide will form and is distinguishable by a black powder. The mercury, the mercury reservoir, and tube will all need to be cleaned. Keep in mind that mercury is toxic and care should be used to not release any into the ground or building. Check the leather seal and washer located at the top of the upright tube. Pump the pumping bulb: as soon as the pumping is stopped, the mercury should stop rising. If it continues to rise, the leather seal and washer will have to be further investigated and perhaps replaced.

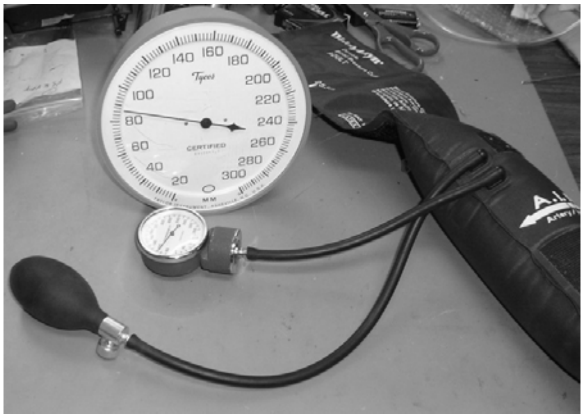
For automatic NIBP's the most common problem is the use of the incorrect cuff. If the correct cuff is being used, and if the transducer is located in the cuff itself, it may be possible to access the transducer with some difficulty. However, repair often requires specialized knowledge, as the manufacturer's designs vary considerably.

For invasive blood pressure measurements, there are many possible problems. The most common is reusing non-reusable transducers. The single use disposable transducers are now the standard of care in the United States. While there are non-disposable alternatives, they are rarely used. The transducer is commonly mounted on an IV pole next to the patient's bed. It should be at the same level as the patient. There is a 2.5 mmHg error for every inch that the transducer is above or below the level correct level.

During the set-up process the invasive catheter transducer is vented to air, zeroed and all the air removed from the line, usually using the flush solution. The technician may, or may not correctly complete each of these steps, leaving air bubbles in the line or leaving the transducer improperly zeroed. Also check that the transducer is at the level of the heart.

2.6.3 Suggested Minimal Testing

The most critical element to calibrate is the pressure measurement. A simple pressure standard can be made by creating a column of water in a tube. Taping a tube to the wall and filling it with water up to a height of 271 cm, for example, creates a pressure standard of 200 mmHg (the density of mercury is 13.55 times that of water). Before releasing the blood pressure machine, check several pressure levels (200 mmHg, 100 mmHg and 50 mmHg – or 271 cm H_20, 136 cm H_20 and 68 cm H_20, respectively). The manometer should be accurate to within 1-3 mmHg.



A manometer can be tested against a known good manometer, against a mercury manometer, or against a simple column of water in an IV tube (100 mmHg of pressure is exerted by a column of water 135 cm high).

If the pressure is consistently too high or too low, you will need to adjust the zero by removing or adding mercury or twisting the manometer face (if aneroid). Electronic blood pressure devices will have a zero setting which should never need to be adjusted, if the device is properly zeroed before each use. There is a gain setting for electronic devices that occasionally needs to be adjusted.

If the blood pressure machine is intended for manual use, you should also check the device for convenience of use. When inflated with the valve closed, the pressure should not drop appreciably in ten seconds. When the valve is open, the pressure should drop slowly and linearly. Consult with the physician or nurse about the leak and drop rates to be sure that the device will be convenient for them to use.

If a mercury manometer has been used for many years, mercuric oxide may form in the tube and will appear as a black powder. The mercury, tube, and reservoir will all have to be cleaned if the nurse objects to its presence. Keep in mind that mercury is toxic and should not be touched or the vapors excessively inhaled. To remove the mercuric oxide, take off the reservoir cap and remove the mercury using a needle and syringe. Filter the mercury through filter paper into a clean container. Repeat several times until all the solid oxide is removed. Take the tube and reservoir outside and use an air line to blow out any particulate matter. Replace the clean mercury into the reservoir and top off the reservoir with new mercury up to the '0' mark. Replace the reservoir cap.

Automatic, non-invasive blood pressure machines (NIBP's) are more difficult to calibrate than the others because the need to detect the Kortokoff sounds to function. If you do not have a phantom arm, then the best approach is to use your own arm. Borrow a stethoscope and measure your own BP. If you are not confident that you can use a sphygmomanometer accurately, then ask someone else to measure your BP. Repeat the measurement five times. Then connect yourself to the NIBP and measure your blood pressure five times. The average diastolic and systolic pressures from the two systems should match to within 3 mmHg.

Malkin, R. "Blood Pressure Machines," From the publication: Medical Instruments in the Developing World. Engineering World Health, 2006.

Sphygmomanometer Introduction

Chapter 4.17 Sphygmomanometers (B.P. sets)

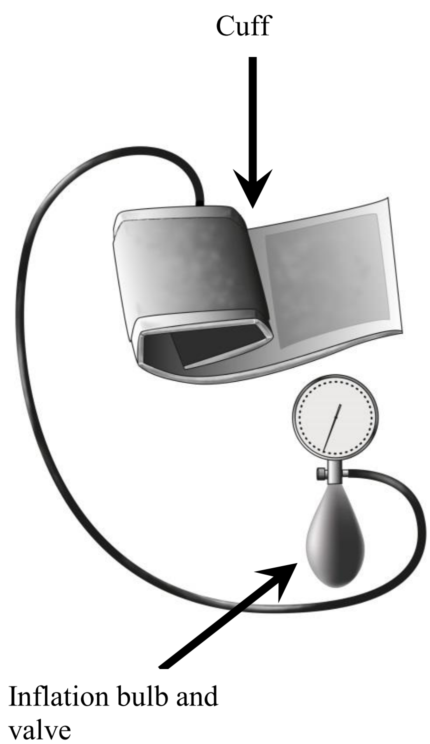
Function

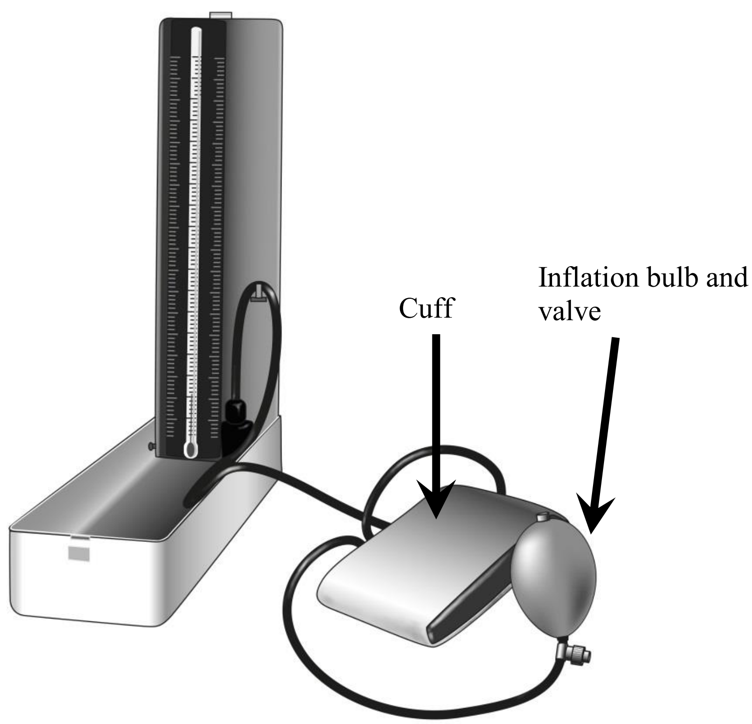
Blood pressure is an indicator of several diseases as well as of general health. It is an easy screening test using simple equipment. A sphygmomanometer can be used to measure the blood pressure at the high point (systolic) and low point (diastolic) of the cardiac pressure cycle. Pressure is usually measured using a cuff on the upper arm.

How it works

The cuff on the arm is inflated until blood flow in the artery is blocked. As the cuff pressure is decreased slowly, the sounds of blood flow starting again can be detected. The cuff pressure at this point marks the high (systolic) pressure of the cycle. When flow is unobstructed and returns to normal, the sounds of blood flow disappear. The cuff pressure at this point marks the low (diastolic) pressure.

Pressure can be measured using a meter with dial (aneroid type), a mercury column or an electronic display. The sounds are normally detected using a stethoscope, but some electronic equipment uses a different, automatic technique with pressure sensors. The two methods do not always give the results and the stethoscope method is generally seen to be more accurate for all types of patient.





Strengthening Specialised Clinical Services in the Pacific. User Care of Medical Equipment: A first line maintenance guide for end users. (2015).

Stethoscope Introduction

User Care of Medical Equipment – First line maintenance for end users

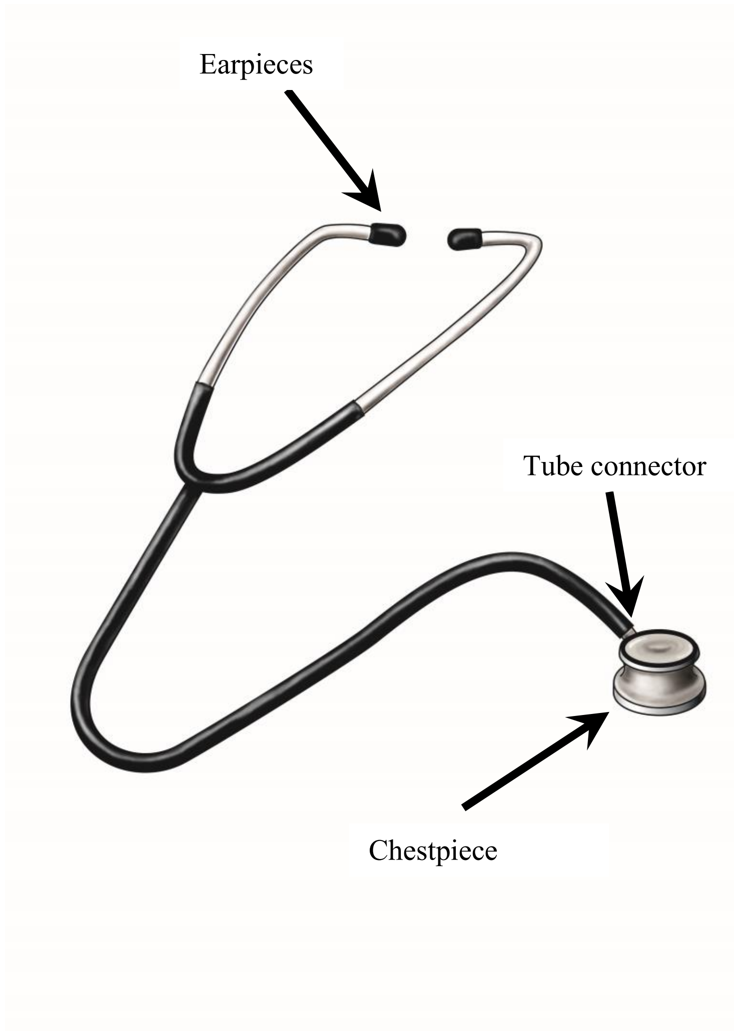
Chapter 4.18 Stethoscopes

Function

A stethoscope is used to listen to sounds within the body. These might be sounds generated by breathing, coughing, blood flow or the stomach. The sounds are picked up and transmitted to the ears of the medical staff for diagnosis.

How it works

A membrane on the stethoscope chestpiece picks up the vibrations caused by internal sounds and transmits them to the stethoscope tube. The sounds pass up the tube through the earpiece to the user. The stethoscope chestpiece also contains an open bell which is used to pick up lower frequency sounds. The head picks up the sound from a wide area so it sounds loud to the user. Care must therefore be taken not to hit or shout into the stethoscope while in use.



Strengthening Specialised Clinical Services in the Pacific. User Care of Medical Equipment: A first line maintenance guide for end users. (2015).

2. Diagrams and Schematics of Blood Pressure Machines

Featured in this Section:

Cooper, Justin and Alex Dahinten for Engineering World Health. “Blood Pressure Monitor (Manual) Troubleshooting Flowchart.” From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Cromwell, L. et. al. “Blood Pressure Measurement.” From the publication *Biomedical Instrumentation and Measurements*. Prentice Hall (1973), pgs. 208-232.

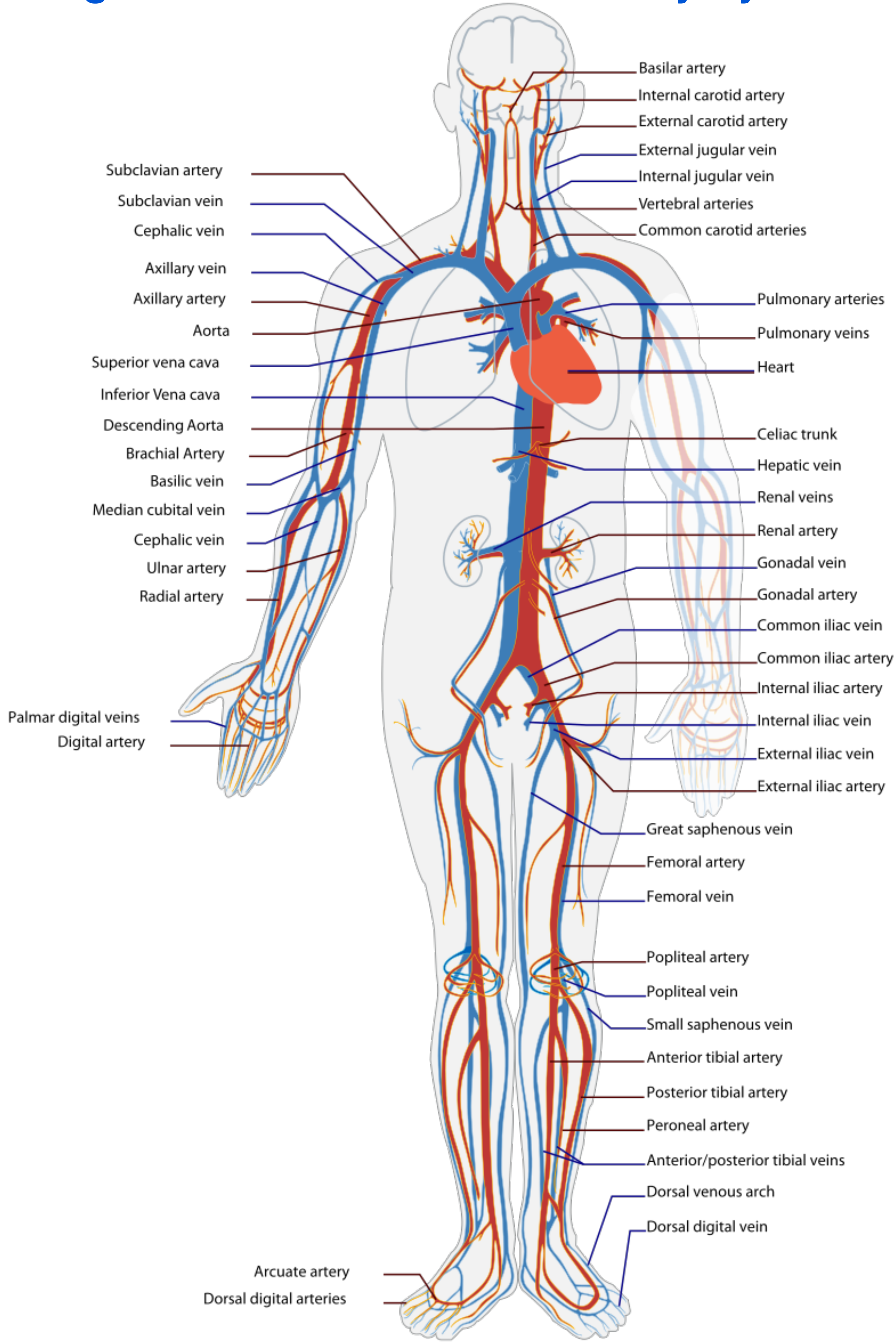
NIH Senior Health. “High Blood Pressure: Symptoms and Diagnosis.” NIH. Last updated 2014. Retrieved from: http://nihseniorhealth.gov/highbloodpressure/symptomsanddiagnosis/01.html

Wikipedia. “Circulatory System en. Svg.” Wikipedia Commons: May 2009. Retrieved From: https://en.wikipedia.org/wiki/File:Circulatory_System_en.svg

Figure 1: Equipment Used to Manually Measure Blood Pressure

NIH Senior Health. "High Blood Pressure: Symptoms and Diagnosis." NIH. Last updated 2014. Retrieved from: http://nihseniorhealth.gov/highbloodpressure/symptomsanddiagnosis/01.html

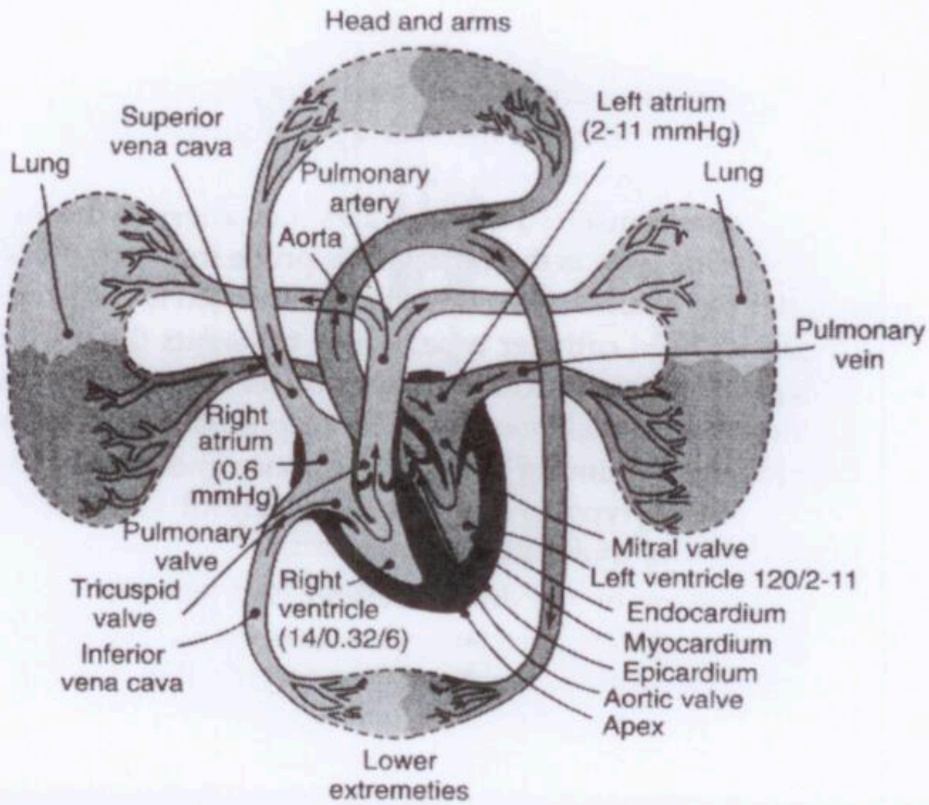
Figure 2: The Human Circulatory System



Wikipedia. "Circulatory System en. Svg." Wikipedia Commons: May 2009. Retrieved From: https://en.wikipedia.org/wiki/File:Circulatory_System_en.svg

Figure 3: Pressure Valves of the Circulatory System

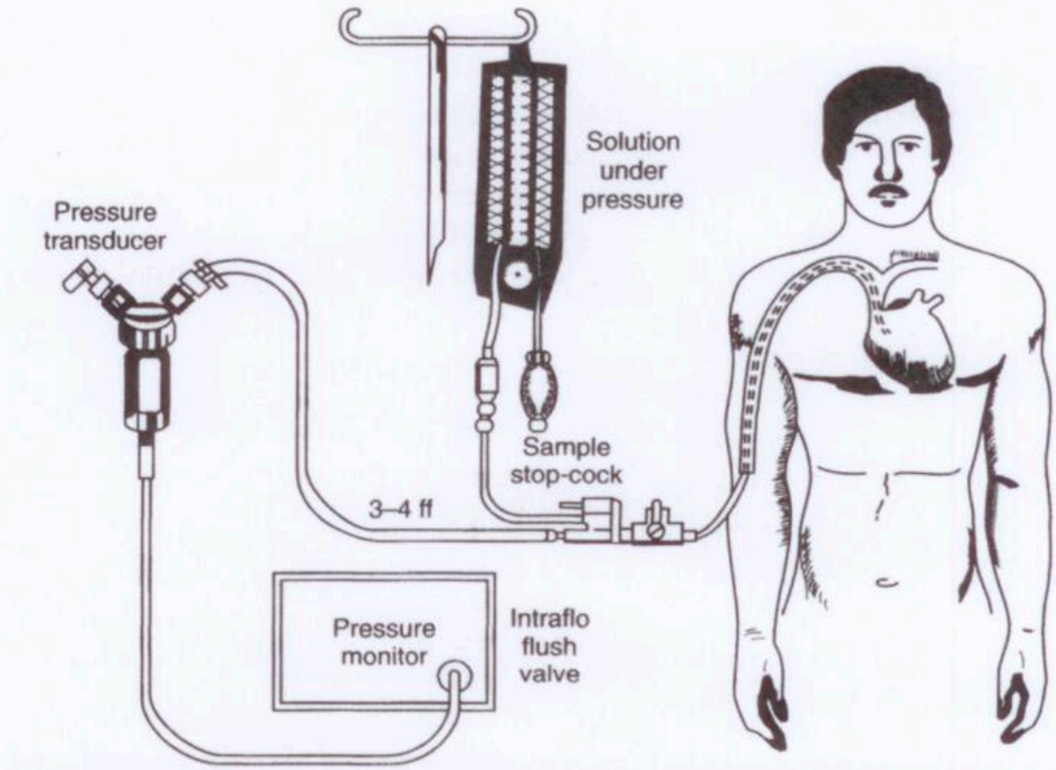
Patient Monitoring Systems **209**



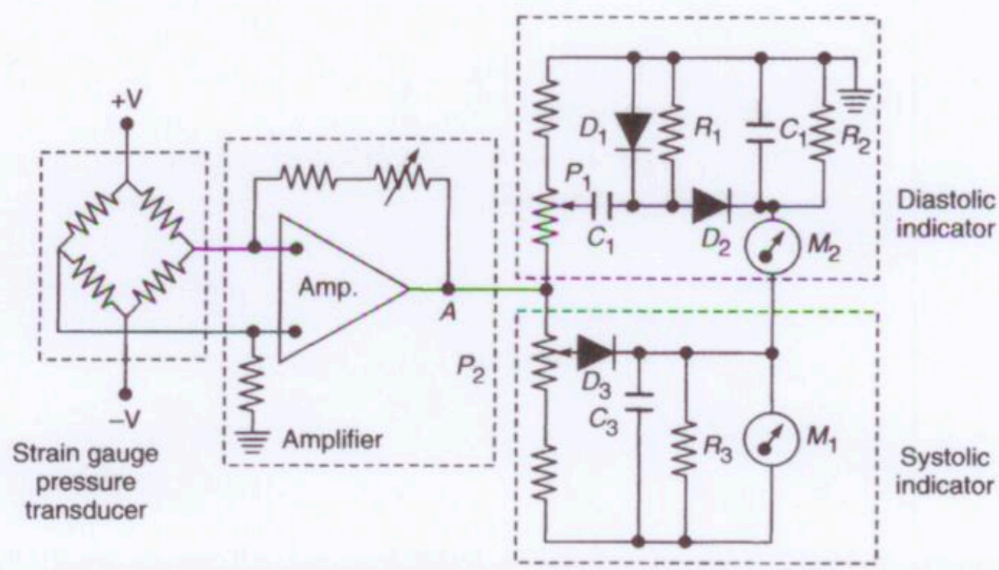
➤ **Fig. 6.18** ***Typical haemodynamic pressure values present in the basic circulatory system (Courtesy: Hewlett Packard, USA)***

Cromwell, L. et. al. "Blood Pressure Measurement." From the publication Biomedical instrumentation and Measurements. Prentice Hall (1973), pgs. 208-232.

Figure 4: Setup of a Pressure Measuring System & Circuit Diagram



➤ **Fig. 6.19** *Typical set up of a pressure measuring system by direct method*



➤ **Fig. 6.20** *Circuit diagram for measurement of systolic and diastolic blood pressure*

Cromwell, L. et. al. "Blood Pressure Measurement." From the publication Biomedical instrumentation and Measurements. Prentice Hall (1973), pgs. 208-232.

Figure 5: Fundamentals Parts of NIBP (Non-Invasive Blood Pressure) Measuring System

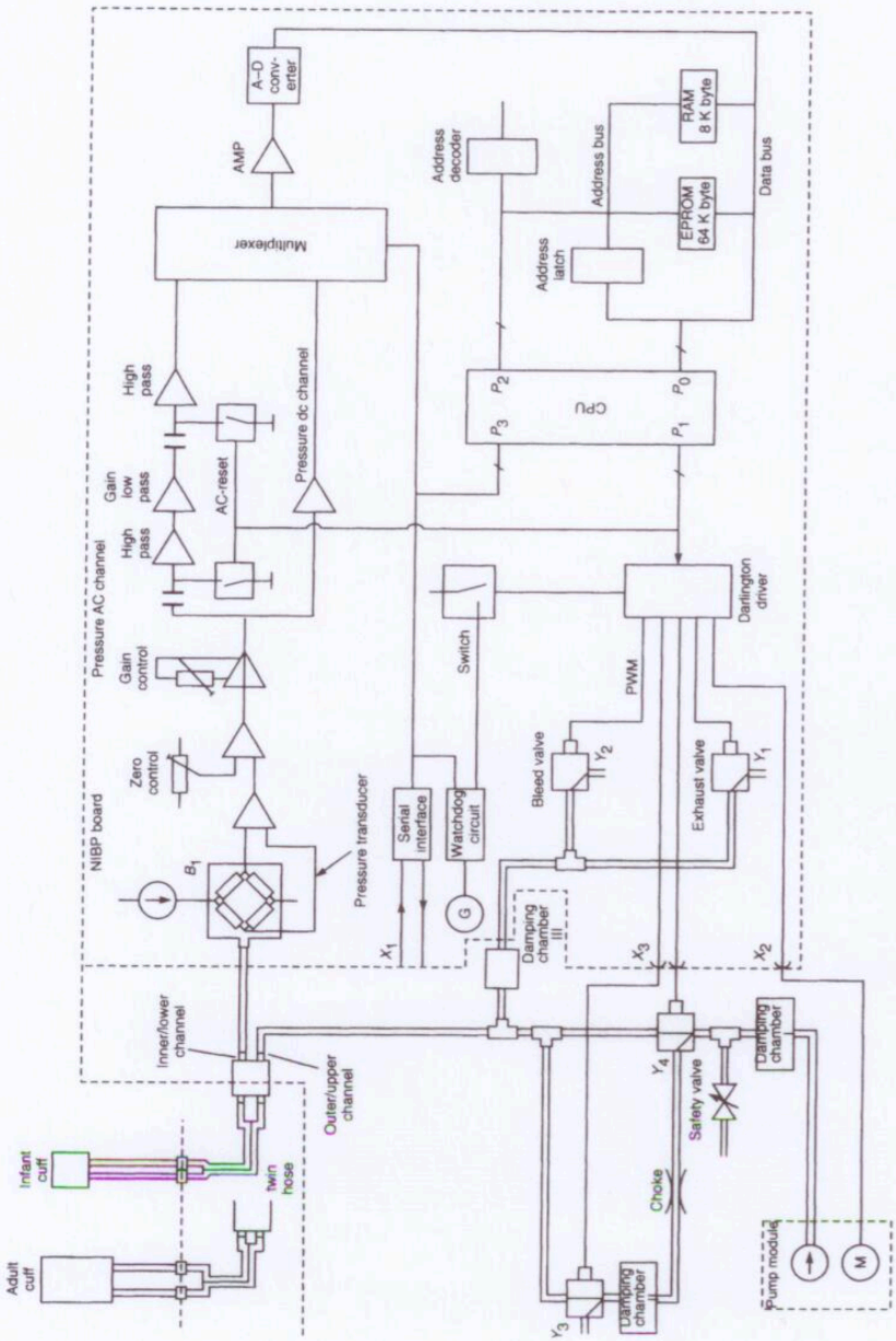
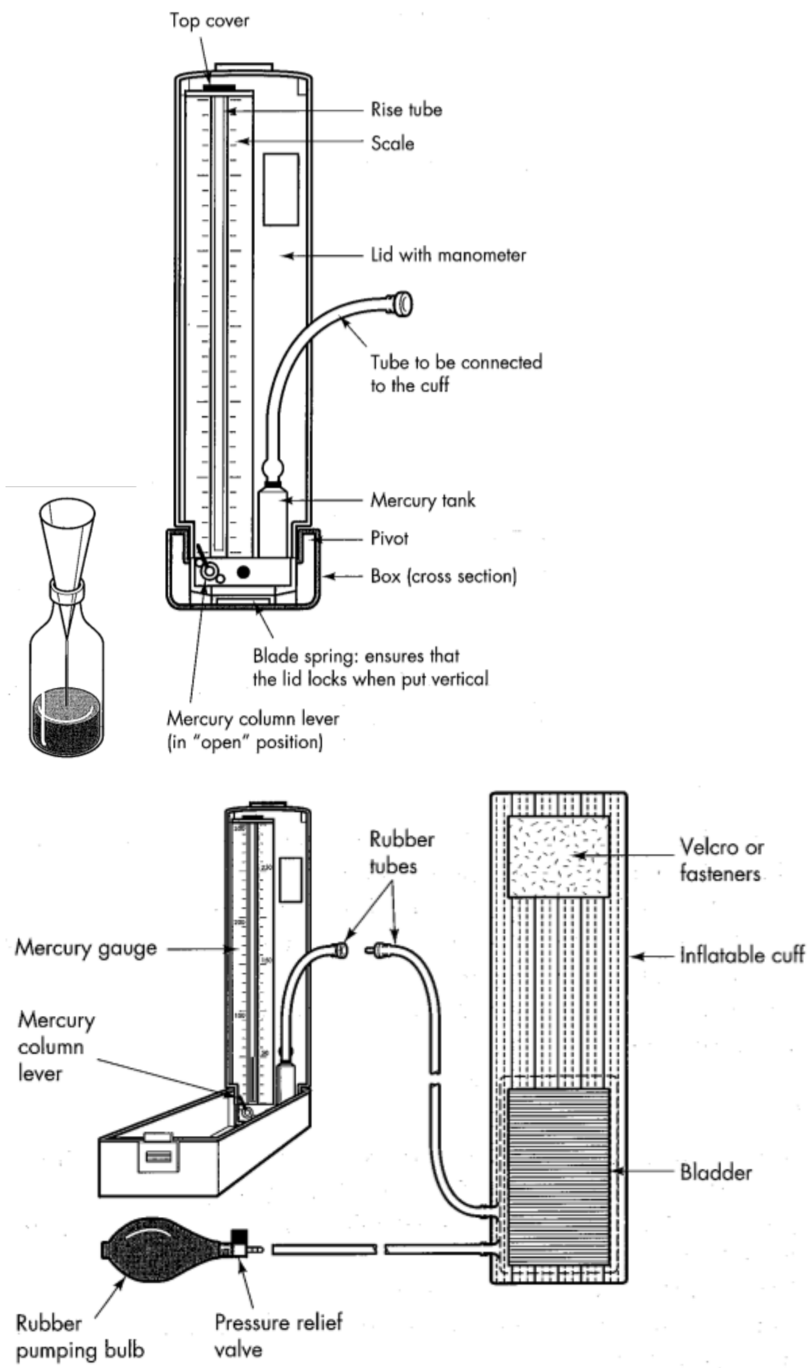


Fig. 6.33 *Fundamental parts of NIBP measuring system*

Cromwell, L. et. al. "Blood Pressure Measurement." From the publication Biomedical instrumentation and Measurements. Prentice Hall (1973), pgs. 208-232.

Figure 6: How To Take Blood Pressure



How To: Take Blood Pressure

1. Prepare the patient. o Sitting down

o Arm unobstructed

o Ask about blood pressure history

2. Wrap the cuff around the upper arm with leads facing the brachial artery.

Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Manual) Preventative Maintenance." From the publication Medical Equipment Troubleshooting Flowchart Handbook. Durham, NC: Engineering World Health (2013).

Should be about level with the heart. Be sure that it is the proper cuff size for the patient's arm.

3. Put on stethoscope. Listen to the brachial artery very close to the cuff.

4. Ensure that the knob is turned completely clockwise.

5. Pump the cuff to a high pressure (for adults: 160-180 mmHg, for children: 140 mmHg)

6. Carefully turn the knob counterclockwise to release the pressure in the cuff at a slow rate.

7. Look at the pressure on the dial while listening to the heartbeat through the stethoscope.

8. Obtain and record the blood pressure.

○ Systolic: the pressure at which you start to hear the heart beat ○ Diastolic: the pressure at which you stop hearing the heart beat

Examples of ranges for healthy blood pressures:

Age	**BP (Systolic/ Diastolic)**
Child, <6 months	90-105/70
Child, 6 months to 7 years	105-117/70
Adult	120/80

3. Preventative Maintenance and Safety of Blood Pressure Machines

Featured in this Section:

Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Automatic) Preventative Maintenance." From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Manual) Preventative Maintenance." From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Strengthening Specialised Clinical Services in the Pacific. *User Care of Medical Equipment: A first line maintenance guide for end users*. (2015).

Blood Pressure Monitor (Automatic) Preventative Maintenance

Preventive Maintenance

- Check power supply. If the machine uses batteries, check their voltage and replace when output is low. If wall input is utilized, ensure that the proper power is being used.
- Inspect power cords and plugs. Check AC plug for loose or damaged parts. Verify proper insulation and integrity of cords.
- Assess for leaks, cracks, and occlusions in the cuff, connections, and tubing inside and outside apparatus. Inspect all fittings and connectors.
- Inspect inside circuitry. Verify that all switches operate properly as well.
- Check that any alarms go off when the measured blood pressure is outside of an acceptably healthy, that is if the NIBP has this capability. The clinical staff should establish this range. To test this on yourself, set the parameters such that they should go off when you take your own blood pressure. Once you are assured that the alarms are functional, be sure to set the parameters back!
- Perform a self-test on the BP cuff to ensure cuff is working properly and within reasonably accuracy (±5 mmHg). Accuracy can be determined by having the clinical staff take your blood manually.

How To: Taking Blood Pressure

1. Prepare the patient.
   - Sitting or lying down
   - Arm unobstructed
   - Ask about blood pressure history
   - Ensure that it is a quiet space and that the patient doesn't move too much – many NIBPs are sensitive to noise and movement
2. Wrap the cuff around the upper arm with leads facing the brachial artery. Be sure that it is the proper cuff size for the patient's arm. The cuff should be about 1-2 cm above the elbow and about level with the patient's heart.
3. Turn on the machine, and press "start" when ready to measure blood pressure.
4. Have the patient remain still and quiet until a blood pressure is displayed. Often times a pulse rate will also be measured and displayed.
5. If the patient has a higher than usual blood pressure, many NIBPs will allow the user to hold the start button until the monitor inflates 30-40 mmHg higher than the expected blood pressure.
6. If the cuff needs to be deflated or reset during inflation for any reason, press the off button.
7. Record the blood pressure.

Examples of ranges for healthy blood pressures:

Age	BP (Systolic/ Diastolic)
Child, <6 months	90-105/70
Child, 6 months to 7 years	105-117/70
Adult	120/80

MANUAL Blood Pressure Monitor Preventative Maintenance

Equipment

Blood Pressure Monitor

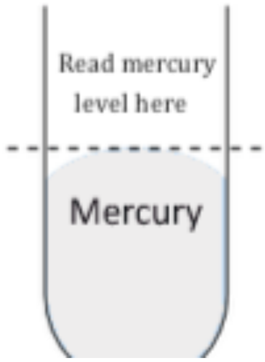
Preventative Maintenance

How To: Dissemble a Mercury Manometer

- Remove the cuff and tubing from the mercury apparatus
- Open the mercury column lever, and tilt the apparatus back to allow any mercury in the column to run into the reservoir
- Remove the tank cover (usually using a screwdriver)
- Remove all mercury from the tank using a syringe
- Pour mercury into a clearly labeled container, following proper protocol
- Remove cover over the rise tube (usually using a screwdriver)
- Take out the rise tube

How To: Clean Mercury

- Roll a sheet of paper into a funnel
- The pointed end should have a tiny hole
- Put the funnel in a bottle
- Pour the mercury into the funnel and let pass through



How To: Mercury-Handling Protocol

- When exposed to air, mercury vaporizes and is extremely poisonous
- Always handle mercury while wearing rubber gloves
- Work with mercury outside or in a well-ventilated area
- Recover mercury with a large syringe
- When storing mercury, add some water to prevent evaporation
- Always have an airtight cover on a mercury container
- Wash skin thoroughly if it comes into contact with mercury

Sphygmomanometer Preventative Maintenance Checklist

User Care of Medical Equipment – First line maintenance for end users

User Care Checklist – Sphygmomanometers (B.P. sets)

Daily	
Cleaning	✓ If mercury is spilled, seal unit and send to technician
Visual checks	✓ Ensure all parts are present and are tightly fitted ✓ Check display is zero when cuff deflated
Function checks	✓ Before use, check pressure rises and returns to zero ✓ Check equipment is safely packed

Weekly	
Cleaning	✓ Remove all dust and dirt with damp cloth or by hand
Visual checks	✓ Remove or replace any cracked rubber parts
Function checks	✓ Check correct operation of inflation bulb and valves ✓ Remove any batteries if not in use for more than one month ✓ Inflate to 200 mmHg and check leakage is not faster than 2 mmHg in 10 seconds

Every six months
✓ Biomedical Technician check required ✓ Check calibration of aneroid devices against mercury device

Strengthening Specialised Clinical Services in the Pacific. User Care of Medical Equipment: A first line maintenance guide for end users. (2015).

Stethoscope Preventive Maintenance Checklist

User Care Checklist – Stethoscopes

Daily	
Cleaning	✓ Remove any dirt visible
Visual checks	✓ Check all parts are present and tightly fitted
Function checks	✓ Tap chestpiece gently before use to check operation ✓ Check equipment is safely packed

Weekly	
Cleaning	✓ Remove all dirt with damp cloth or by hand ✓ Remove earpieces and clean inside with warm water
Visual checks	✓ Remove or replace any cracked rubber parts ✓ Replace membrane if broken
Function checks	✓ Check tube connector rotates easily within chestpiece ✓ Check sound can be heard from both sides of chestpiece

Every six months
Biomedical Technician check required

Strengthening Specialised Clinical Services in the Pacific. User Care of Medical Equipment: A first line maintenance guide for end users. (2015).

4. Troubleshooting and Repair of Blood Pressure Monitors

Featured in this Section:

Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Automatic) Troubleshooting Flowchart." From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

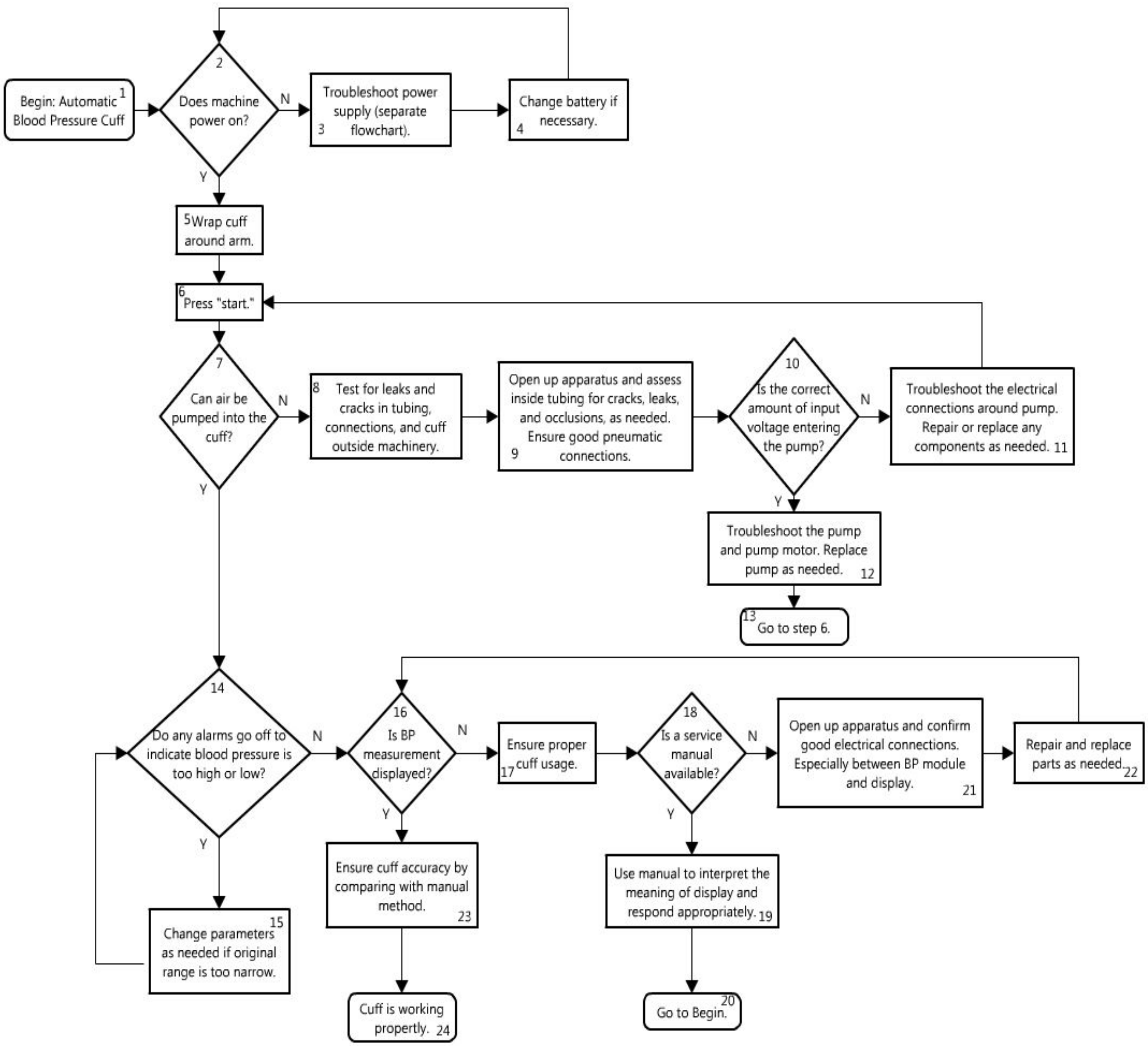
Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Manual) Troubleshooting Flowchart." From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Strengthening Specialised Clinical Services in the Pacific. *User Care of Medical Equipment: A first line maintenance guide for end users*. (2015).

AUTOMATIC Blood Pressure Monitor Troubleshooting Flowchart

Blood Pressure Monitor (Automatic) Troubleshooting Flowchart:

Flowchart



Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Automatic) Troubleshooting Flowchart." From the publication Medical Equipment Troubleshooting Flowchart Handbook. Durham, NC: Engineering World Health (2013).

Description

#	Text Box	Comments
1	Begin: Automatic Blood Pressure Cuff	Testing and maintenance is advised when the automatic blood cuff fails to give out a complete or accurate blood pressure.
2	Does machine power on?	Lights, displays, and sounds are signs that the device is powered on.
3	Troubleshoot power supply (separate flowchart).	NIBP (Noninvasive Blood Pressure) machines have varying sources of power. Some require batteries, and others can be plugged directly into the wall. It is always best to ensure that the proper power is being administered. Machines requiring 110-120V, for example, should not be plugged into a socket with a power of 220-240V without the proper transformer. See Flowchart on Power Supply, or BTA skills on Power Supply.
4	Change battery if necessary.	If batteries are required, test that they are able to receive and hold a charge. See BTA skills on Batteries.
5	Wrap cuff around arm.	Try wrapping cuff around your arm before beginning function test. NIBP will require either pulses or vibrations brachial artery, so it is important that the cuff is on correctly. Follow the **User Guide** for more detailed instructions.
6	Press "start."	For some machines, a flashing light or image will suggest the machine is ready to begin the blood pressure measurement.
7	Can air be pumped into the cuff?	Once engaged, the machine's pump will begin inflating the cuff. Does the cuff readily inflate? Is a reading able to be obtained?
8	Test for leaks and cracks in tubing, connections, and cuff outside machinery.	Use BTA skills on Connections, Leaks and Blockages to assess for cracks, leaks, or occlusions.
9	Open up apparatus and assess inside tubing for cracks, leaks, and occlusions, as needed.	If cuff still has difficulty inflating, carefully open the apparatus and observe what happens to inside tubing when the pump is activated. Listen for escaping air and use BTA skills on Connections, Leaking, Seals and Blockages to assess, replace, repair, or clean tubing and parts as needed.
10	Is the correct amount of input voltage entering the pump?	Test the voltage going into the pump using a multimeter. Compare the measured voltage to the required DC input voltage, which can usually be found as a marking somewhere on the pump.
11	Troubleshoot the electrical connections around pump. Repair or replace any components as needed.	If the pump is not receiving the proper input voltage, this has something to do with the electrical circuitry or connections supplying power to the pump. Use BTA skills on Electrical Simple to observe, assess, and repair any circuit components and connections.

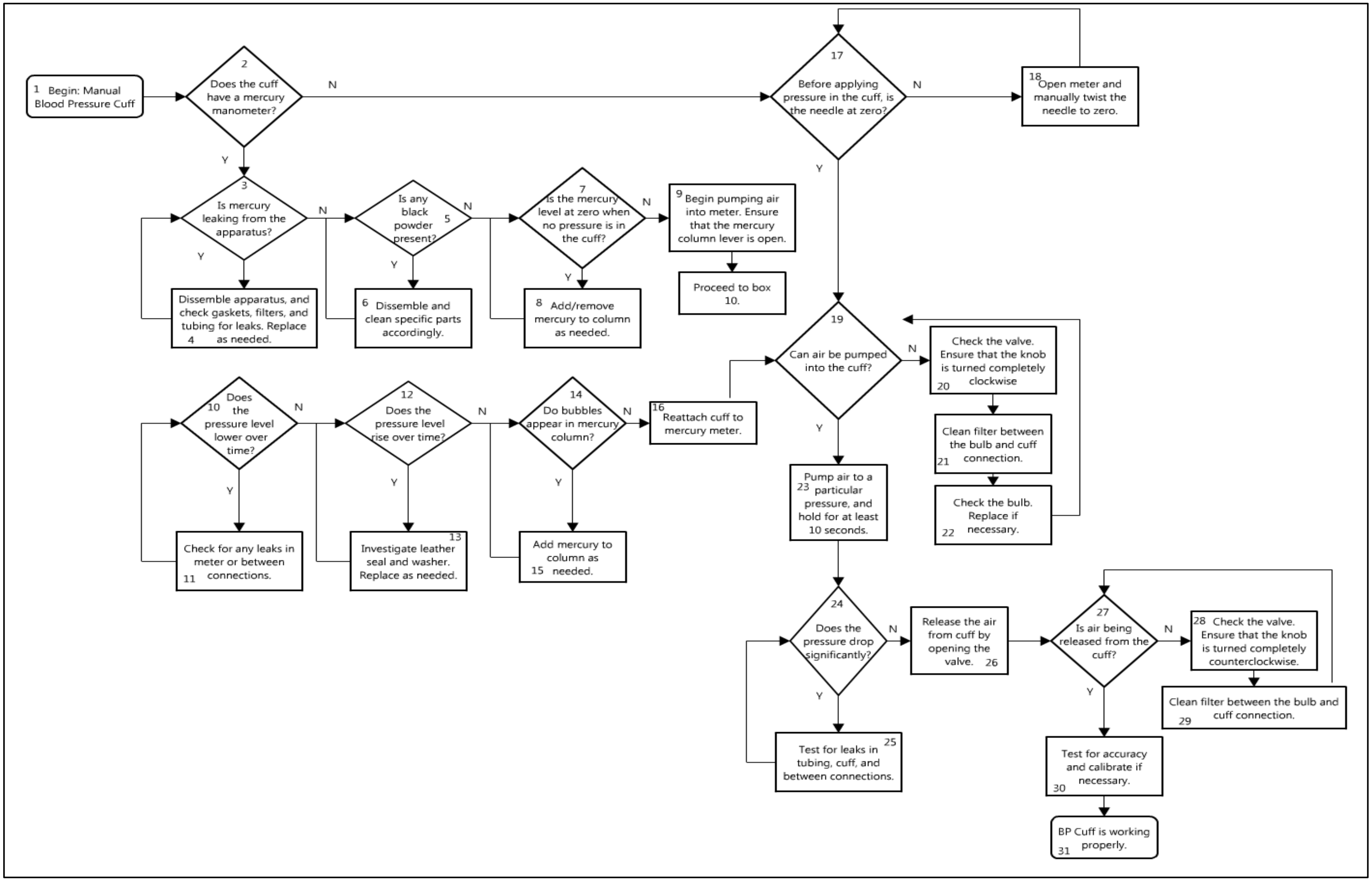
Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Automatic) Troubleshooting Flowchart." From the publication Medical Equipment Troubleshooting Flowchart Handbook. Durham, NC: Engineering World Health (2013).

12	Troubleshoot the pump and pump motor. Replace pump as needed.	If the pump is receiving the proper input voltage, but still not properly inflating the cuff, try troubleshooting the pump and its motor using BTA skills on Motors and Mechanical. Pump may have to be replaced if irreversibly damaged.
13	Go to step 6.	Restart cuff inflation to see if the corrective measures have repaired the machine.
14	Do any alarms go off to indicate blood pressure is too high or low?	Some NIBP machines are equipped with alarms that indicate whether or not a blood pressure is within an acceptable healthy range, preset by the machine's parameters.
15	Change parameters as needed if original range is too narrow.	If machine parameters are causing alarms to go off when a healthy blood pressure is causing the alarms to go off, it may be possible to change them. Check parameters by pressing the "menu" button, if applicable. Consult with clinical staff to see how these parameters should be set.
16	Is BP measurement displayed?	After pressing start, is a numerical value for blood pressure displayed? NIBPs will usually display a systolic, diastolic, and pulse rate after measurement.
17	Ensure proper cuff usage.	Is the cuff the proper size for your arm or the patient's arm? Are the leads in the cuff over the brachial artery? NIBPs can be very sensitive. Check the **User Guide** to ensure proper machine usage.
18	Is a service manual available?	Many service manuals will instruct the user on the meaning of displayed error messages for the specific NIBP system. These messages can also point to general areas of the device that can be troubleshot using the relevant BTA skills.
19	Use manual to interpret the meaning of display and respond appropriately.	Most of the time these messages are accompanied by a proposed set of actions.
20	Go to Begin.	Restart diagnostic process to see if the corrective measures have repaired the machine.
21	Open up apparatus and confirm good electrical connections. Especially between BP module and display.	Sometimes a problem in the circuit is to blame for inaccurate or incomplete measurements. Use BTA skills on Electrical Simple to observe, assess, and repair any circuit components and connections.
22	Repair and replace parts as needed.	If there is any obvious damage, repair connections and replace necessary parts using the appropriate BTA skills.

23	Ensure cuff accuracy by comparing with manual method.	After obtaining a blood pressure measurement, have the clinical staff take a blood pressure on the same individual using a working manual blood pressure cuff. A good NIBP will be within 5 mmHg, but ultimately it is up to the staff whether or not the cuff should be used on patients.
24	Cuff is working properly.	Return apparatus to appropriate clinical staff.

MANUAL Blood Pressure Monitor Troubleshooting Flowchart

Blood Pressure Monitor (Manual) Flowchart:



Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Manual) Troubleshooting Flowchart." From the publication Medical Equipment Troubleshooting Flowchart Handbook. Durham, NC: Engineering World Health (2013).

Description

#	Text Box	Comments
1	Begin: Manual Blood Pressure Cuff	Testing and maintenance is advised when the manual cuff fails to give out a complete or accurate blood pressure.
2	Does the cuff have a mercury manometer?	There are two types of manual blood pressure cuffs, one with a mercury manometer and an aneroid sphygmomanometer with just a small pressure dial.
3	Is mercury leaking from the apparatus?	If there is any mercury escaping the reservoir, proceed with extreme caution and **follow mercury-handling protocols.** See BTA skills for Leaking and Blockages.
4	Disassemble apparatus and check gaskets, filters, and tubing for leaks. Replace as needed.	Disassemble the apparatus (follow protocol below).Assess each part for any leaks and cracks. Replace or repair faulty parts as necessary. See BTA skills on Plumbing and Mechanical.
5	Is any black powder present?	The black powder is oxidized mercury and needs to be removed.
6	Disassemble and clean specific parts accordingly.	Disassemble the apparatus (follow protocol below) If oxide is in rise tube and mercury tank: -Using a stiff wire, push a small piece of cotton or gauze through the rise tube several times -Gently tap mercury tank (with opening facing downwards) onto tray to make sure all mercury has been removed -Wash tube and tank in a detergent and water solution -Dry thoroughly -Clean mercury using protocol below

Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Manual) Troubleshooting Flowchart." From the publication Medical Equipment Troubleshooting Flowchart Handbook. Durham, NC: Engineering World Health (2013).

7	Is the mercury level at zero when no pressure is in the cuff?	Meter should be at zero when no pressure is applied.
8	Add/remove mercury to column as needed.	**Follow mercury-handling protocol.** Any added mercury can be taken from another existing meter that doesn't work correctly or isn't in use.
9	Begin pumping air into meter. Ensure that the mercury column lever is open.	If possible, disassemble tubing, and attach the bulb and its tubing to the meter so that the cuff is not involved in meter testing. Be sure that the mercury column lever is open, or else no mercury will come up the rise tube.
10	Does the pressure level lower over time?	The mercury level will fall if there are any cracks or leaks.
11	Check for any leaks in meter or between connections.	Use BTA skills on Leaking and Seals to assess for cracks or leaks.
12	Does the pressure level rise over time?	Leather seal and washer may be cracked/broken.
13	Investigate leather seal and washer. Replace as needed.	Use BTA skills to assess for cracks or leaks. Leather seal and washer will usually need to be replaced. See BTA skills on Leaking, Seals and Connections.
14	Do bubbles appear in mercury column?	Small air pockets will form if not enough mercury is in the tank.
15	Add mercury to column as needed.	**Follow mercury-handling protocol.** Any added mercury can be taken from another existing meter that doesn't work correctly or isn't in use.
16	Reattach cuff to mercury meter.	Reassemble cuff to meter if the apparatus was dissembled in step 9.

17	Before applying pressure in the cuff, is the needle at zero?	Needle in the dial should be at zero when no pressure is applied.
18	Open meter and manually twist the needle to zero.	Screw off dial cover and use a screwdriver to loosen or remove needle. Reassemble once needle is back at zero.
19	Can air be pumped into the cuff?	Try putting cuff around your arm or a bottle before pumping air. Is there difficultly in pushing air into the cuff? Does it deflate immediately?
20	Check the valve. Ensure that the knob is turned completely clockwise.	Valve must be turned completely clockwise to inflate the cuff.
21	Clean filter between the bulb, valve, and cuff connection.	Remove the valve from the bulb and cuff tubing. Use a screwdriver to scrape out any dirt in valve connection, or see BTA skills on Blockages Reassemble bulb, valve, and cuff tubing.
22	Check the bulb. Replace if necessary.	Is the bulb able to pump air? Are there any holes or leakage in the bulb? Repair with silicon if possible. Bulbs will typically need to be replaced. See BTA skills on Seals and Leaking.
23	Pump air to a particular pressure and hold for at least 10 seconds.	Pump air to a pressure of approximately 180 mmHg for a human arm.
24	Does the pressure drop significantly?	If the pressure drops more than 5 mmHg in 10 seconds, there is probably a leak.
25	Test for leaks in tubing and between connections.	Use BTA skills for cracks or leaks.
26	Release the air from cuff.	Turn knob completely counterclockwise.
27	Is air being released from the cuff?	You will hear air being released from the valve, and the cuff should deflate with no difficulty.

Cooper, Justin and Alex Dahinten for Engineering World Health. "Blood Pressure Monitor (Manual) Troubleshooting Flowchart." From the publication Medical Equipment Troubleshooting Flowchart Handbook. Durham, NC: Engineering World Health (2013).

28	Check the valve. Ensure that the knob is turned completely counterclockwise.	Valve must be turned completely clockwise to deflate the cuff.
29	Clean filter between the bulb and cuff connection.	Remove the valve from the bulb and cuff tubing. Use a screwdriver to scrape out any dirt in valve connection, or see BTA skills on Blockages. Reassemble bulb, valve, and cuff tubing.
30	Test for accuracy and calibrate if necessary.	Use BTA skills on Calibration to calibrate sphygmometer.
31	BP cuff is working properly.	Return apparatus to appropriate clinical staff.

Sphygmomanometer Troubleshooting Checklist

Troubleshooting – Sphygmomanometers (B.P. sets)

	Fault	Possible Cause	Solution
1.	Mercury leakage OR Mercury not at zero level	Mercury leakage or overfilling	Refer to technician for correction
2.	Mercury is dirty	Oxidation of mercury	Refer to technician for cleaning
3.	Pressure does not increase easily OR Pressure increases after inflation	Valve or tube blockage	Remove and clean all valves and tubes. Reassemble and test
4.	Aneroid instrument does not return to zero	Zero setting has moved	Rotate collar on base until zero setting achieved and tighten. If still malfunctioning, refer to technician
5.	Pressure does not remain steady	Leakage of air	Isolate leak by closing off parts of tubing. Replace leaking section and retest

Stethoscope Troubleshooting Checklist

Troubleshooting – Stethoscopes

	Fault	Possible Cause	Solution
1.	Faint or no sound heard	Leakage or blockage	Remove all parts and check for leakage and blockage. Water or blowing air can be used to flush tubes through. Assemble and retest
2.	Tube connector does not stay in chestpiece	Broken locking mechanism	Refer to technician for repair
3.	Parts damaged or faulty	Broken part	Replace with part taken from other units

Strengthening Specialised Clinical Services in the Pacific. User Care of Medical Equipment: A first line maintenance guide for end users. (2015).

5. Resources for More Information

Featured in this Section:

Skeet, Muriel and David Fear. “Blood Pressure Apparatus.” *Care and Safe Use of Medical Equipment*. VSO Books, 1995.

WHO. “Blood Pressure Machines (Sphygmomanometers).” *Maintenance and Repair of Laboratory, Diagnostic Imaging, and Hospital Equipment* (WHO: 1996).

Resources for More Information:

Internal Resources at library.ewh.org: For more information about maintenance and repair of blood pressure monitors please see these resources in the BMET Library!

1. Skeet, Muriel and David Fear. "Blood Pressure Apparatus." *Care and Safe Use of Medical Equipment*. VSO Books, 1995.

2. WHO. "Blood Pressure Machines (Sphygmomanometers)." *Maintenance and Repair of Laboratory, Diagnostic Imaging, and Hospital Equipment* (WHO: 1996).

Blood Pressure Monitor Bibliography

Cooper, Justin and Alex Dahinten for Engineering World Health. “Blood Pressure Monitor (Automatic) Preventative Maintenance.” From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Cooper, Justin and Alex Dahinten for Engineering World Health. “Blood Pressure Monitor (Manual) Preventative Maintenance.” From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Cooper, Justin and Alex Dahinten for Engineering World Health. “Blood Pressure Monitor (Automatic) Troubleshooting Flowchart.” From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Cooper, Justin and Alex Dahinten for Engineering World Health. “Blood Pressure Monitor (Manual) Troubleshooting Flowchart.” From the publication *Medical Equipment Troubleshooting Flowchart Handbook*. Durham, NC: Engineering World Health (2013).

Cromwell, L. et. al. “Blood Pressure Measurement.” From the publication *Biomedical Instrumentation and Measurements*. Prentice Hall (1973), pgs. 208-232.

Skeet, Muriel and David Fear. “Blood Pressure Apparatus.” *Care and Safe Use of Medical Equipment*. VSO Books, 1995.

Malkin, R. “Blood Pressure Machines,” From the publication: *Medical Instruments in the Developing World.* Engineering World Health, 2006.

NIH Senior Health. “High Blood Pressure: Symptoms and Diagnosis.” NIH. Last updated 2014. Retrieved from: http://nihseniorhealth.gov/highbloodpressure/symptomsanddiagnosis/01.html

Strengthening Specialised Clinical Services in the Pacific. *User Care of Medical Equipment: A first line maintenance guide for end users*. (2015).

WHO. “Blood Pressure Monitor,” From the publication: *Core Medical Equipment*. Geneva, Switzerland, 2011.

Wikipedia, “Blood Pressure.” Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Blood_pressure

Wikipedia. “Circulatory System en. Svg.” Wikipedia Commons: May 2009. Retrieved From: https://en.wikipedia.org/wiki/File:Circulatory_System_en.svg

Wikipedia, “Pulse Pressure.” Wikipedia, p. 1-12. Date retrieved: September, 16, 2015. Retrieved from: https://en.wikipedia.org/wiki/Pulse_pressure