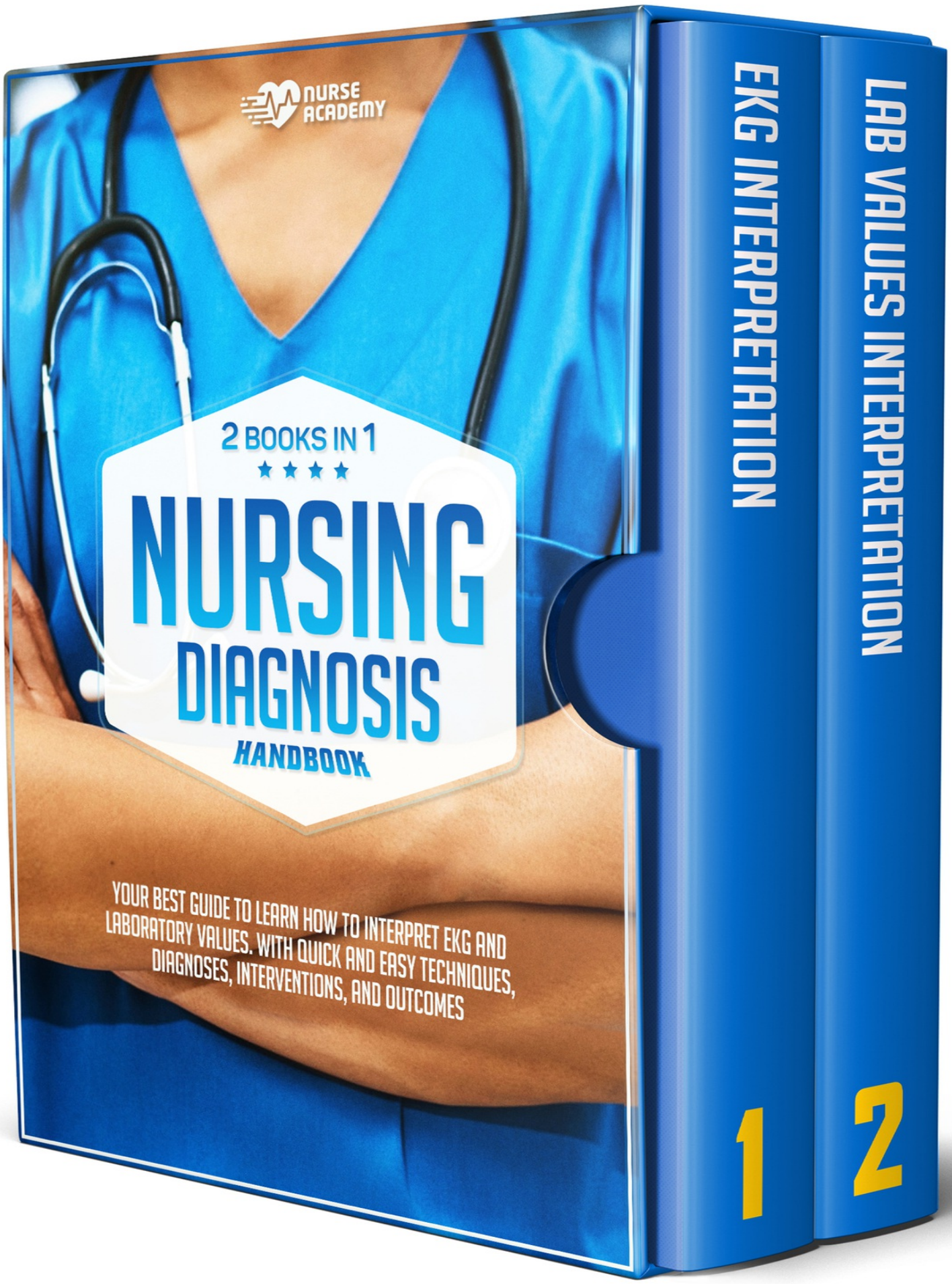
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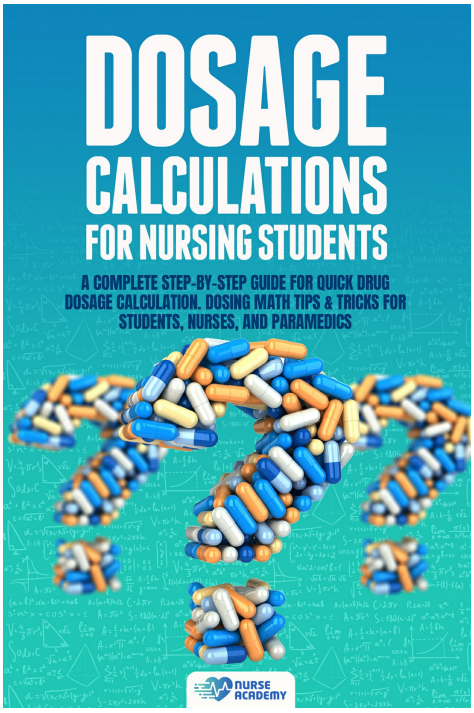

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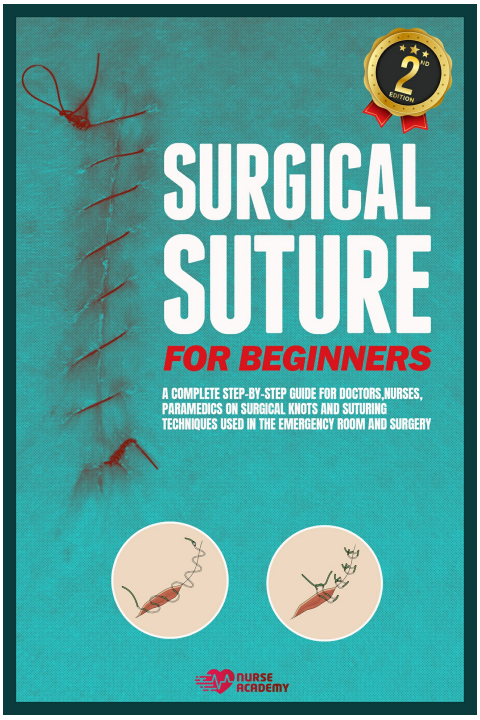

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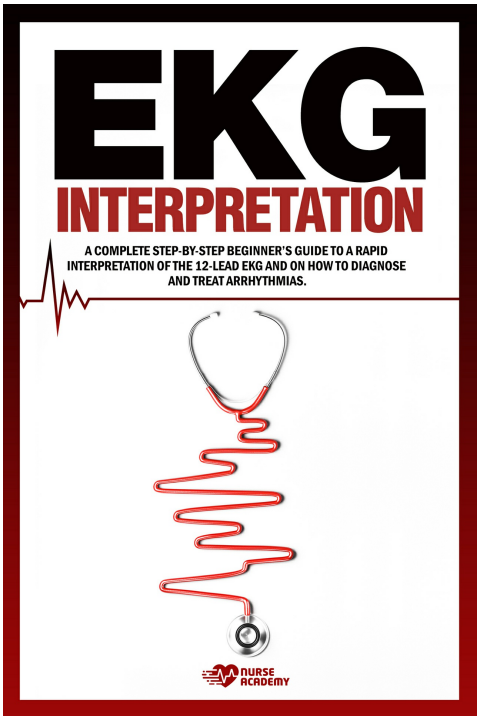
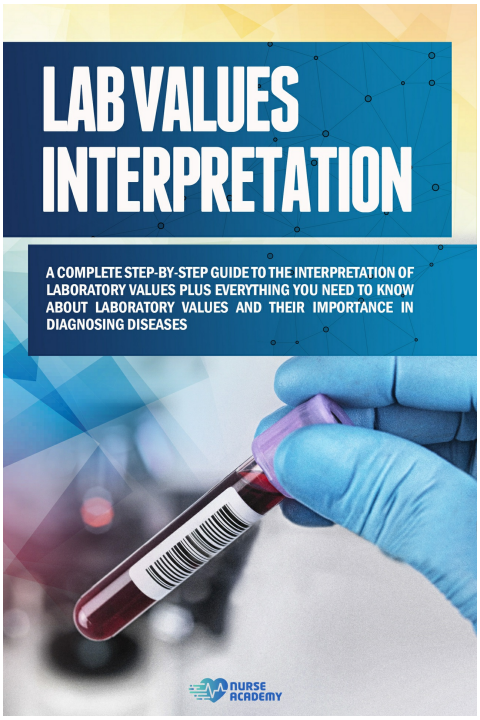
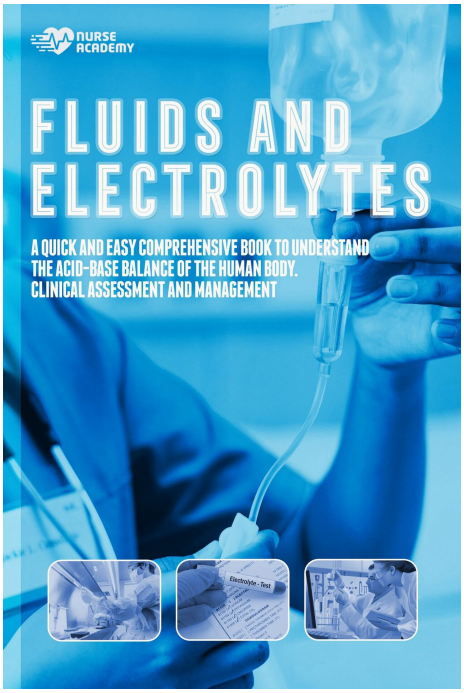


EKG INTERPRETATION



LAB VALUES INTERPRETATION



FLUIDS AND ELECTROLYTES

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EKG INTERPRETATION

LAB VALUES INTERPRETATION

Ekg Interpretation

A complete step-by-step beginner’s guide to a rapid interpretation of the 12-lead EKG and on how to diagnose and treat
arrhythmias.

Introduction

The first recording in a human of the electrical potentials generated by the heart from the body surface (electrocardiogram) is believed to have been obtained in London, in 1869 or 1870, by Alexander Muirhead, a telegraph engineer. He used equipment designed to record signals from the newly laid transatlantic cable.

The first detailed description of the electrocardiogram was published by Augustus Waller in 1887. Dr. Waller produced his recordings using a device known as a capillary electrometer. He called his recording a "cardiograph." His early recording apparatus included a photographic plate mounted on a toy train. Many of Waller’s early cardiographs were obtained from his bulldog, Jimmie, which led to him having to defend himself against charges of animal cruelty leveled by the humane society. Fortunately, he convinced the House of Commons that recording an EKG was not cruel.

It was only after the introduction of the more convenient string galvanometer, developed by Willem Einthoven in 1903, that clinical electrocardiography became practical. Einthoven, the "father of electrocardiography," received the Nobel Prize for Medicine, in 1924, for his studies of cardiac electrical activity. It is Einthoven who discovered that the essential waves recorded by electrocardiograms were those that had been labeled "P," "Q," "R," "S," and "T." His paper, written in German, discussed the elektrokardiogramm, thus explaining the use of the abbreviation "EKG."

The electrocardiogram (ECG or EKG) is a device that detects the electrical activity of the heart

for heart problems to be diagnosed. It displays this as line tracings that are printed on paper.
An ECG and an EKG are one and the same. The German translation for electrocardiogram is elektro-kardiographie, which is shortened to EKG.
An ECG/EKG has numerous uses:
When combined with special algorithms (calculations), this device can study multiple biometrics (measurements related to a person's biology), as follows:
Although the ECG gives us several details about the heart, it cannot predict if the person will have a heart attack or when it will happen. It may not adequately pick-up heart problems; someone with heart disease may have a normal EKG. Because of this, the doctors will also look at other factors such as the medical history, other symptoms present, physical examinations, and additional tests.
Sometimes, a problematic EKG output only registers during exercise, scenarios when the heart is stressed, or while the patient is currently experiencing the symptoms. For these instances, ambulatory (walking) and stress EKGs are done.
An EKG done while a person is having a heart attack may seem ordinary or the same as his/her previous EKGs. When this happens, the EKG is repeated over a period of time, such as over several hours or a few days to detect significant changes. These are labelled as serial EKGs.

The heartbeat is the ECG. Nodes generate electrical impulses which are **VERTICAL PLANE LEADS (I, II, III, AVR, AVL, AVF)** conducted through channels, eventually reaching the heart muscle to prompt contraction, which is represented on the ECG. Hence, any problems occurring along this pathway or involving any of the structures comprising it elicits some deviation from the regular ECG reading. We will soon realize that this is nearly ALL cardiac diseases. This is why being adept at the ECG is of such importance.

Chapter 1. Anatomy of The Heart

The human heart is a muscular hollow organ. Its size is approximately equal to the closed fist of a person, but It is responsible for pumping blood throughout the body.
Heart consists of four muscular chambers:

- Right Atrium
- Right Ventricle
- Left Atrium
- Left Ventricle

These four chambers are separated by each other through four valves.

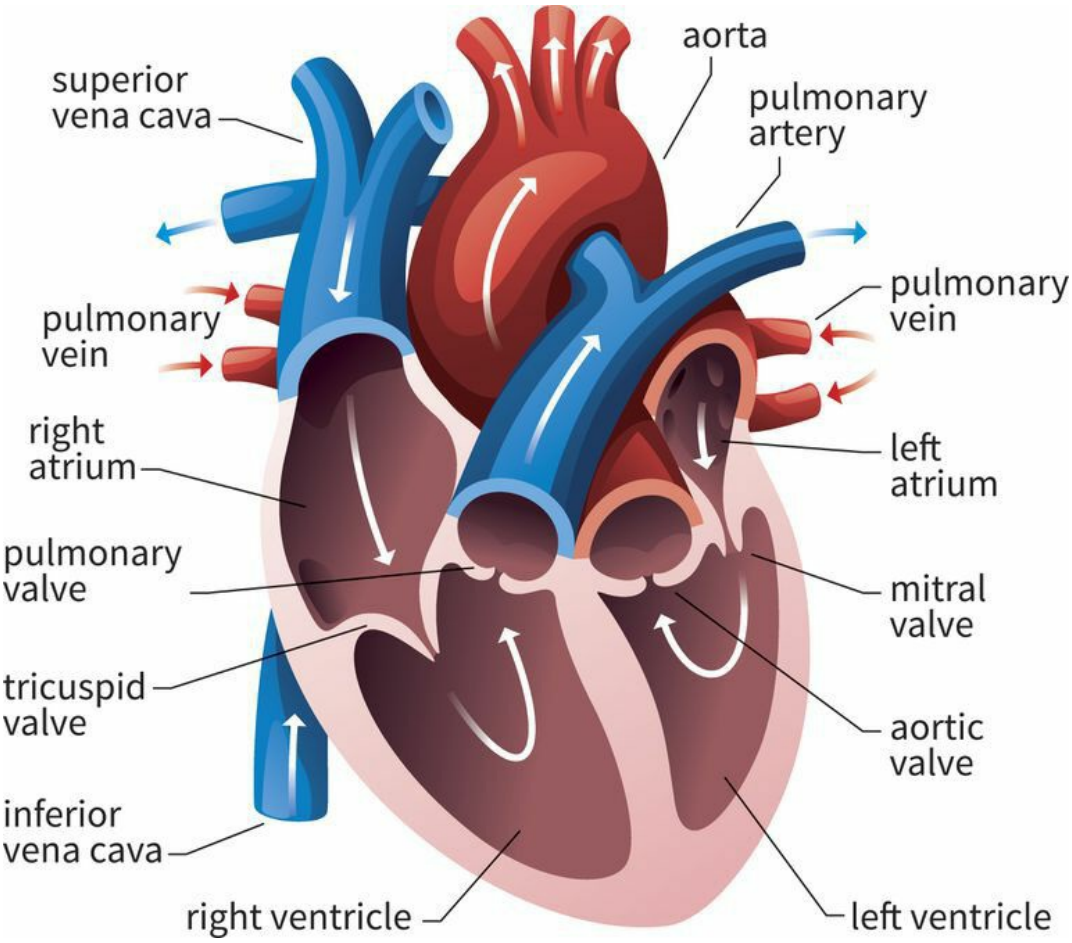
- Aortic valve
- Pulmonary valve
- Bicuspid valve
- Tricuspid valve

Both ventricles are separated by each other through the interventricular septum.
The interatrial septum separates both atria.
Four main layers are:

- Pericardium
- Epicardium
- Myocardium
- Endocardium

Four major vessels attaching with heart:

- Pulmonary arteries
- Pulmonary veins
    - Aorta
    - Superior and Inferior vena cave



Heart Chambers

Anatomically heart is a single structure, but physiologically, the heart is divided into two sides: the right and left sides**.**

The right side of the heart consists of the **right atrium and right ventricle.**

The left side of the heart consists of the **left atrium and left ventricle.**

The heart's right side and left sides are anatomically separate by **the atrial septum and the ventricular septum.**

The two sides of the heart are two separate pumps and primarily work independently of each other.

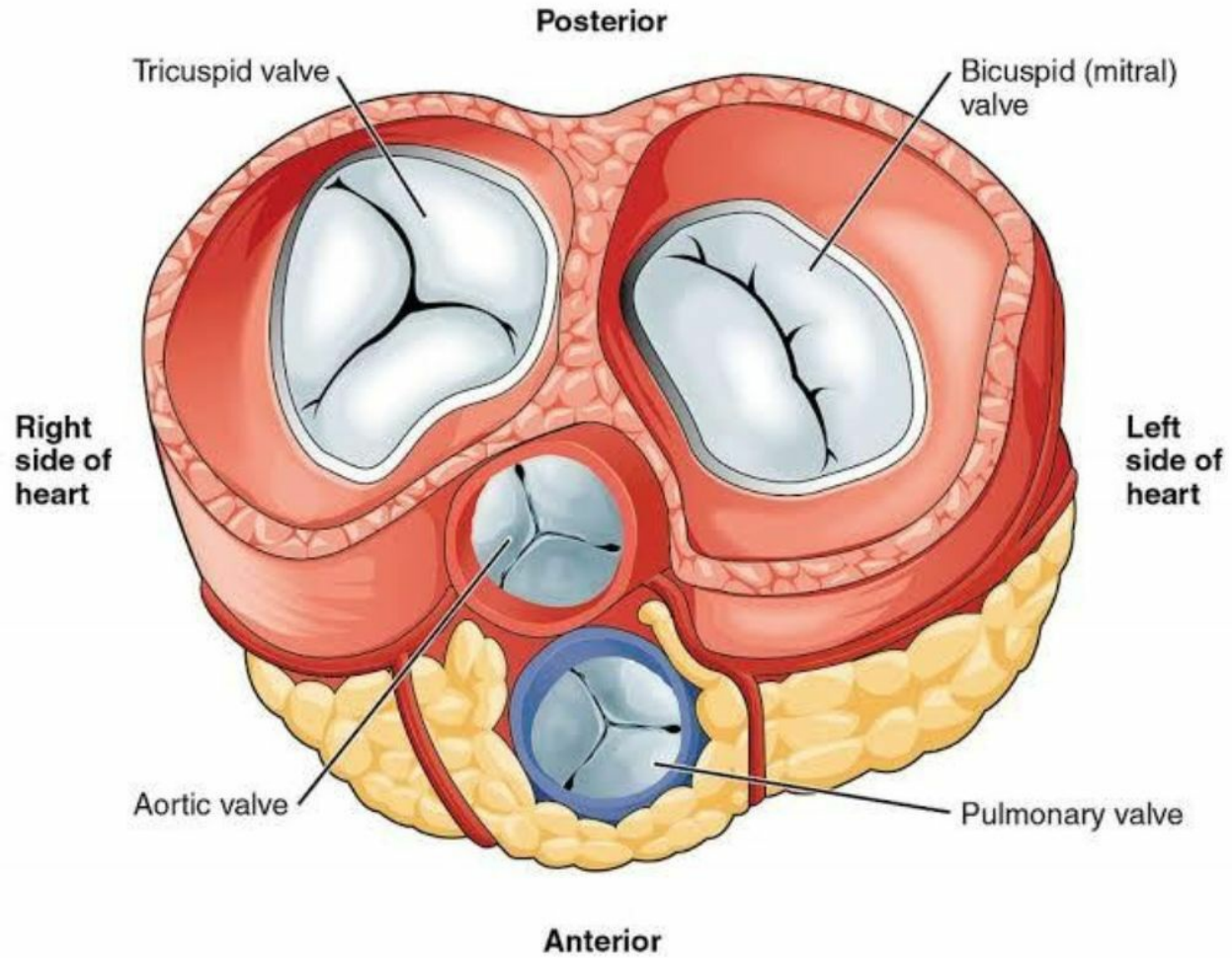
Both atria are smooth-walled low-pressure chambers mainly designed to receive blood from attached vessels.

While both ventricles have thick muscular walls to catch blood from atria and pressure them into attached vessels, the walls of the left ventricle are flashy and more muscular than the right ventricle.

The interventricular septum is more muscular and thicker as compared to the interatrial septum.

Heart Valves

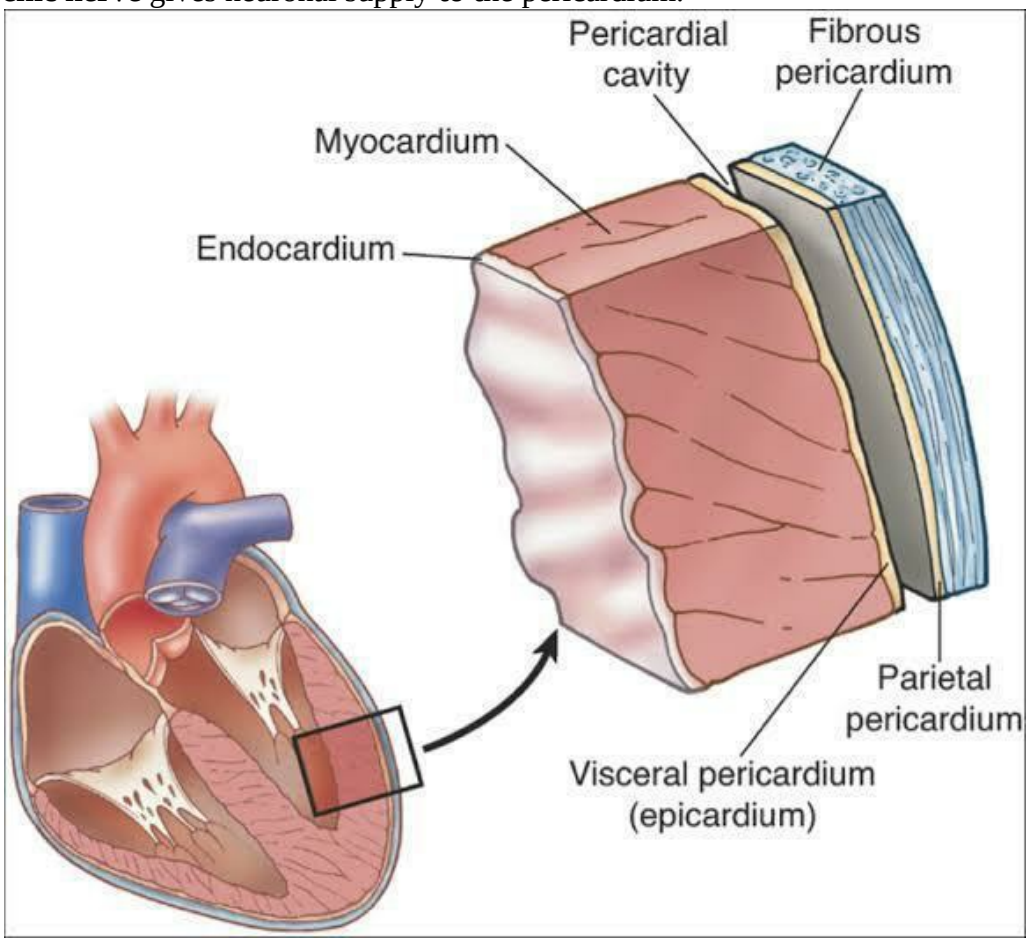
The right atrium is separated by the Right ventricle through the **tricuspid valve**. It is named because it has three cusps.
There is a bicuspid valve present between the left atrium and the left ventricle, known as the mitral valve.
The pulmonary artery originate from the right ventricle, which is guarded by the **Pulmonary valve,** While Aorta arises from the left ventricle separated by the **Aortic valve.**
The aortic and pulmonic valves are also known as semilunar valves because of their distinct half-moon appearance.
The central role of these valves is to prevent the backflow of blood.



Layers of the Heart

The outermost layer of the heart muscle is known as **Epicardium**. The other name of epicardium is the visceral pericardium.
The **myocardium is the mid-layer of the heart,** which is the thick muscular layer and is responsible for the heart's ability to contract.
The innermost layer is the **endocardium**. This layer of the heart lines the valves and chambers.
The **pericardium** is a loose-fitting fibro serous sac that covers the heart. If we are separating the epicardium, the outermost layer of the heart muscle from the pericardium is a space called the

pericardial space or Pericardial cavity. Pericardial Space is full of a fluid that acts as a lubricating agent and protects the heart from injuries caused by friction when it is beating.
The phrenic nerve gives neuronal supply **to t**he pericardium.



The Coronary Circulation

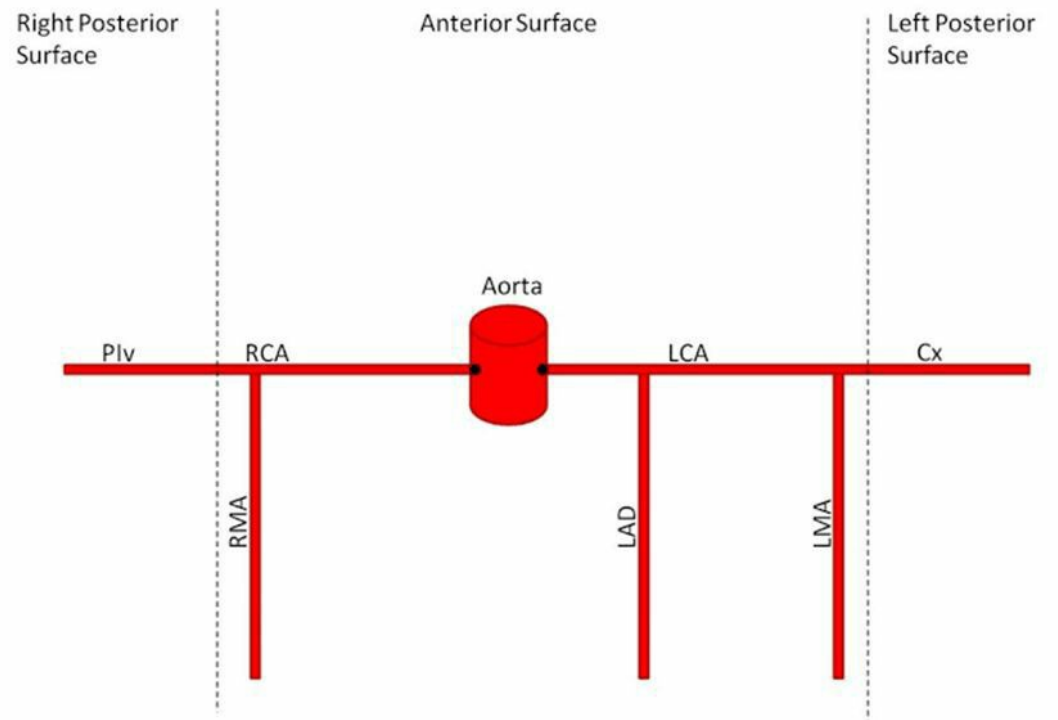
Although the heart provides oxygenated blood to the whole body, the heart muscles themselves can't use it directly. So, there are some specialized blood vessels for heart muscles known as **coronary vessels.**
The two main arteries arise from the **aortic root (part of the Aorta)**. As they travel through the heart, they divide into seven branches. The right coronary artery runs in the coronary sulcus, which is the groove between the atria and the ventricles. Continued posteriorly along the ventricular septum. Its main branches are:

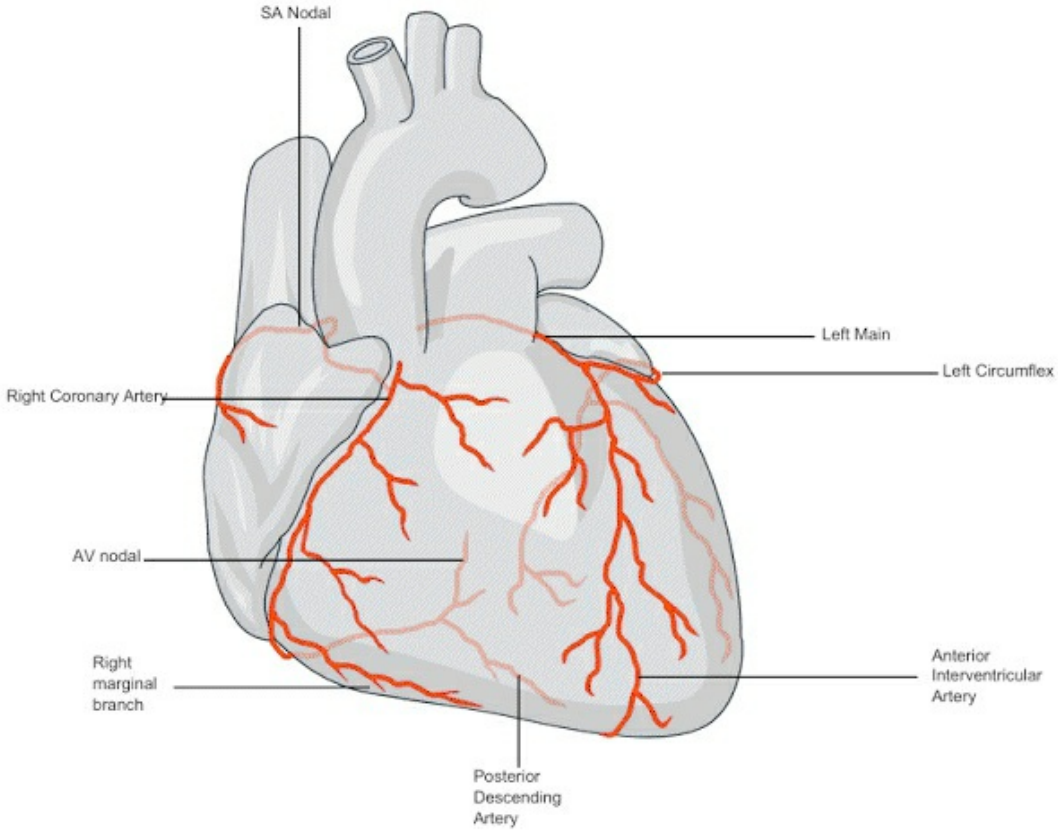
- **Posterior descending branch (PDA) or Posterior interventricular artery (PIV)** supplies AV node, posterior part of the interventricular septum, posterior walls of ventricles.
    - **The right marginal artery** supplying the right ventricle.

The left coronary artery consists of the following main branches

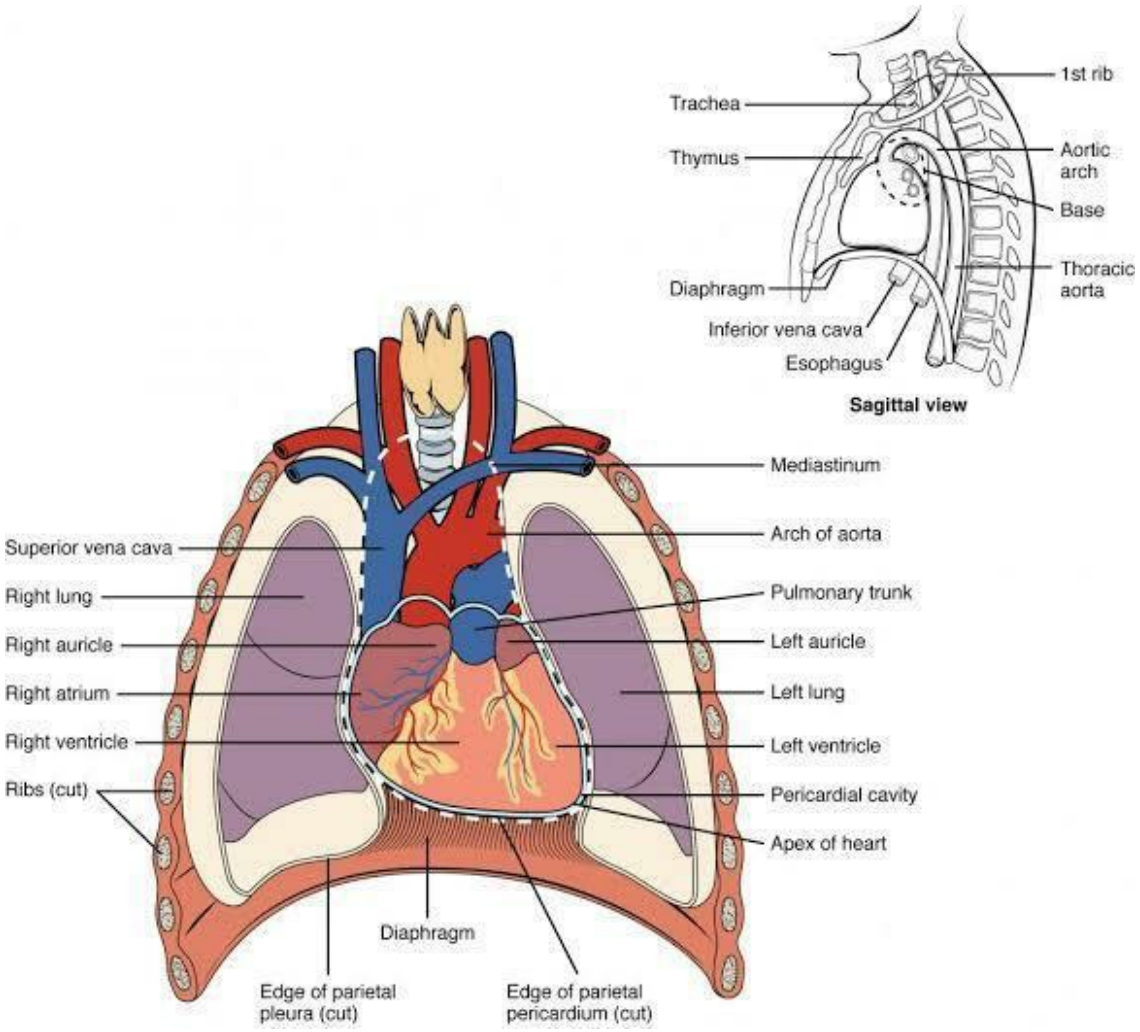
- **Left anterior descending branch (LAD) or Anterior interventricular artery.** The LAD artery perfuses the anterior wall and lateral wall of the left ventricle, the anterior section of the ventricular septum.
    - Left marginal artery (LMA) or Left Obtuse artery.
- **The circumflex branch (CFX):** It is the branch of the left coronary artery that supplies blood to the left atrium and the posterior and lateral walls of the left ventricle.

Blood enters in coronary arteries in the early diastole. These main branches of the coronary arteries typically do not link or anastomose with each other at their ends and are therefore called end arteries.





Anatomical Relations



Surfaces of the heart

Anatomically the heart can be described as having the following surfaces:

Posterior surface (base):

It is directed upward, backward and to the right, formed mainly by the **left atrium** and little by the right atrium.

Apex

It is aimed downward, forward and to the left, formed mainly by the **left ventricle**.

Anterior (sternocostal) surface

It is guided forward, upward, and to the left, formed mainly by the **right ventricle** inferiorly and right atria superiorly.

Inferior (diaphragmatic) surface

It is directed downward, slightly backward, formed by **both ventricles,** which rests mainly upon the central tendon of the diaphragm.

Right surface

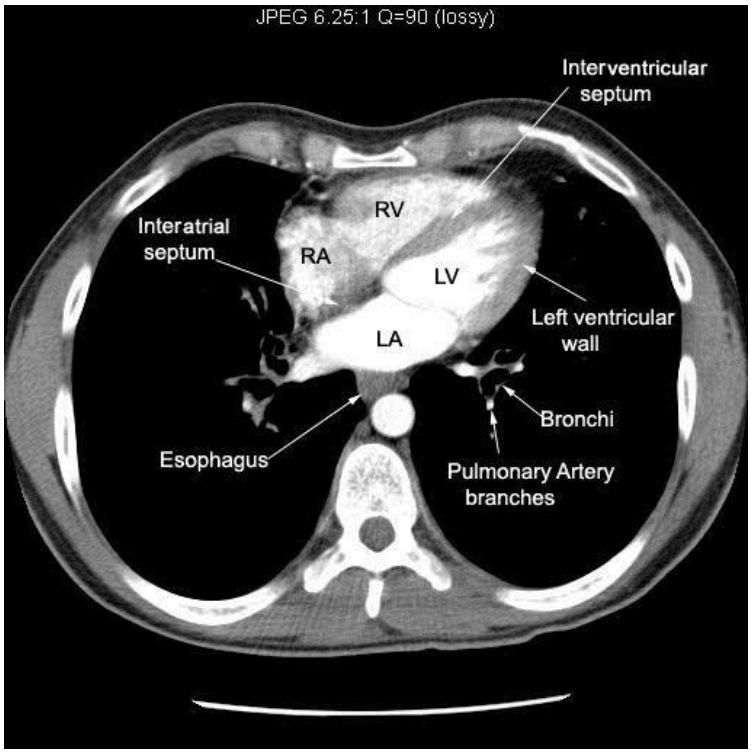
It is long and formed by the **right atrium** superiorly and **right ventricle** inferiorly.

Left (pulmonary) surface.

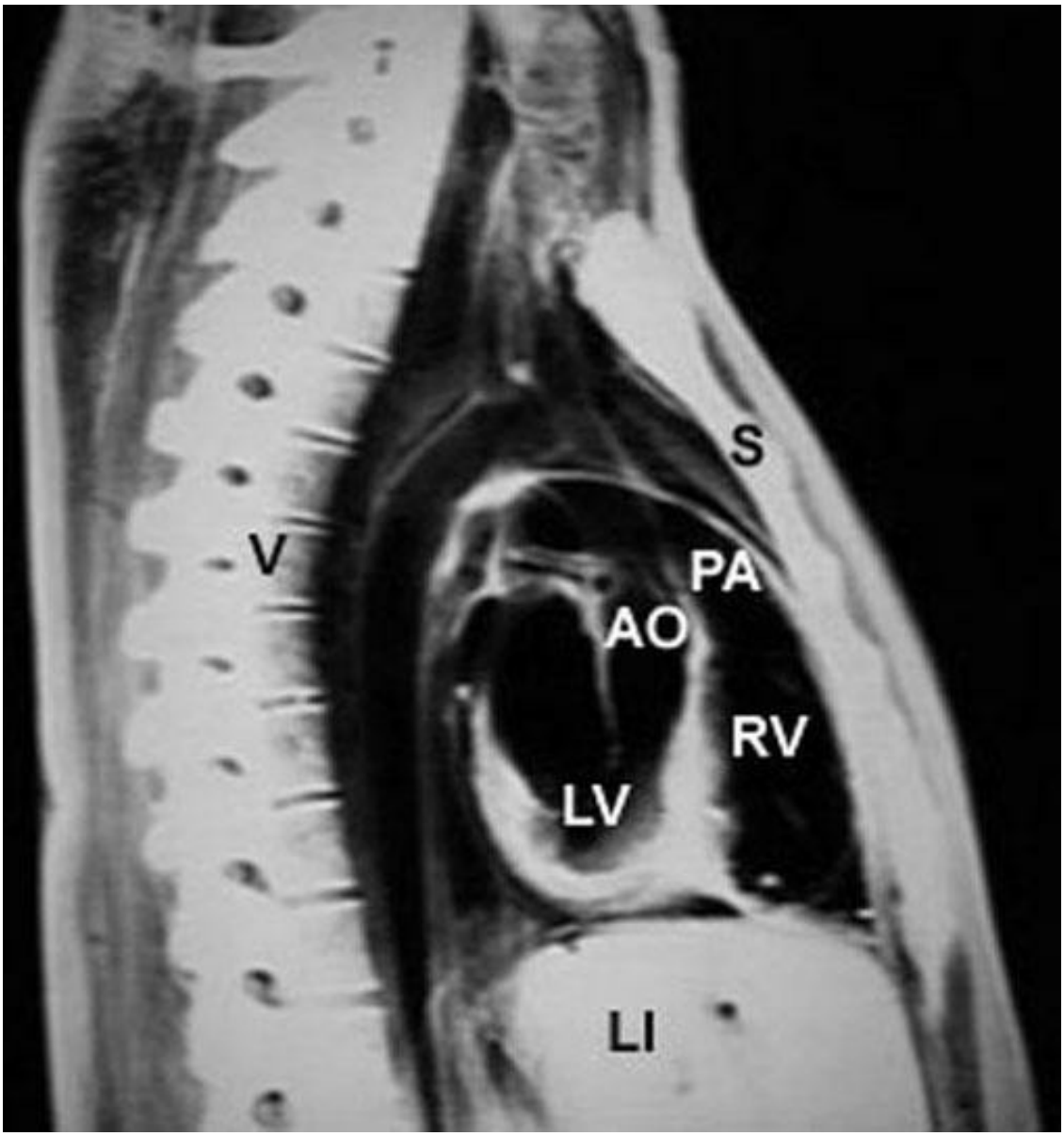
It is shorter and rounded, formed mainly by the **left ventricle** and a little superiorly by the left atrium.

Borders of the heart

The heart has four borders:



RV is the Right ventricle, RA is the Right atrium, LA is the left atrium, LV is the left ventricle.



S=sternum, PA=Pulmonary artery, RV=right ventricle, LV=Left ventricle, AO=Aorta, V=Vertebrae, LI=Liver

To understand the ECG better, it is helpful to study the heart itself. Without this foundational knowledge, the ECG may become undecipherable.

The heart is in the center of the chest, slightly tilting downwards to the left. It is nearer the front of the body than the back.

The heart functions as a pump with four main chambers, with two atria (plural for atrium) and two ventricles. The left ventricle releases blood into the peripheral circulatory system (the blood vessels of the body), while the right ventricle pumps blood into the pulmonary system (lungs).

Oxygen-rich blood from the heart passes through the arteries, while oxygen-depleted blood from the body returns to the heart through the veins.

After oxygen is used by the body cells, the blood is returned to the heart. The right ventricle pushes this through the pulmonary artery and into the lungs, where it is infused with oxygen again. This flows into the left ventricle, which pumps the blood through the Aorta and into the

blood vessels of the entire body.
The right ventricle takes up most of the front part of the heart, but the left ventricle is the one that produces most of the electricity.

Electrical Conduction

The heart has cells that are designed to conduct electricity – some of them are responsible for setting a pace, while others transmit electrical impulses. This is an electrochemical process that happens in the myocardium (heart muscles) found in the walls of the heart.
The atrial myocytes (heart muscle cells) activate each other in sequence. The intermodal pathways carry the impulse from the sino-atrial (SA) node to the atrioventricular (AV) node, reaching the Purkinje system, which goes around the ventricles and energizes the myocardial cells.
These cells set the pace at which the heartbeats. All cells in the conduction system can create a pace, but the rate of each cell type is slower than the rate of those that came before it. Thus, the SA node has the fastest pace; the AV node has the second fastest, and so on, with the last component having the slowest pace. The node with the quickest rate establishes the rate because it resets all the paces of those that come after it. If it malfunctions, the next fastest will serve as its backup, ensuring that the heart beats at near the normal rate.
These are the approximate rates of each component:

SA Node

Found in the wall of the right atrium, the SA node is the primary pacemaker.

Internodal Pathways

The anterior, middle, and posterior pathways (located in the right atrium and interatrial septum - the wall separating the two atria) send the pacing impulses from the SA node towards the AV node. This pathway also consists of the Bachmann bundle, which carries impulses through the inter-atrial septum.

The AV node

Within the right atrium and near the coronary sinus, the AV node slows down the conduction of the atria to the ventricles to enable atrial contraction to occur. Slowing down the pace enables the atria to fill the ventricles and maximizes the output of the heart.

The Bundle of His

The Bundle of His begins at the AV node and splits into the left and right bundle branches. It is partially located in the right atrium walls and in the interventricular septum, which is the partition between the ventricles. This allows for the transmission of impulses between the ventricles and atria.

The Left Bundle Branch

The LBB originates from the end of the His bundle, traverses the interventricular septum, and ends at the start of the left anterior and left posterior fascicles (LAF and LPF). This innervates the left ventricle and the left part of the interventricular septum.

The Right Bundle Branch

This also begins at the His bundle, but it innervates the right ventricle and right part of the interventricular septum. It ends at the Purkinje fibers.

The Left Anterior Fascicle (LAF)

The LAF goes through the left ventricle and reaches the Purkinje cells that innervate the front and top parts of the left ventricle. This consists of a single strand.

The Left Posterior Fascicle (LPF)

The LPF is composed of many strands that lead to the Purkinje cells, which innervate the back and bottom part of the left ventricle.

The Purkinje System

This is composed of cells beneath the inner layer of the heart (myocardium). These directly innervate the cells of the myocardium and start the ventricular depolarization cycle.

Electrolytes

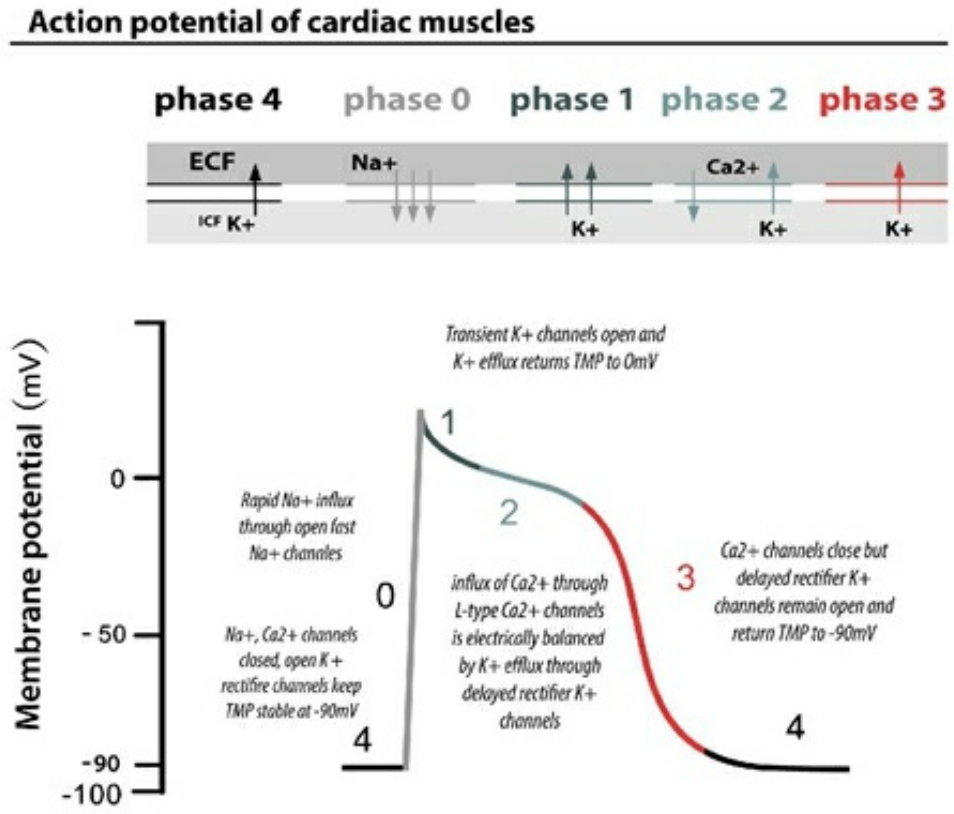
Electrolytes enable cells to generate electricity. They affect how the heartbeats, so you need to have an idea of how they work to interpret an ECG well.

Each cell of the heart (myocardial cell/myocyte) is made of two parts that glide over each other. These partitions are linked to the outside of the cells, and they are made up of myosin molecules that are distributed between actin molecules.

The cells are linked together to create long bands called myofibrils, which in turn are linked together by connective tissue to develop fluid-covered sheets. The bands expand and contract according to the electrical impulse that reaches them.

When one or all the bands in a sheet contract, the sheet shortens. It returns to its original size when all the bands expand. These sheets from the chambers of the heart: the two atria on top and the two ventricles at the bottom. The atria are smaller and thinner than the ventricles below them.

Each cell has fluid inside and outside of it – this contains water, proteins, and salts. When the salts interact with fluid, they break down into particles that have either a positive or negative charge – these are called ions. The positively charged ions, or cations, are potassium, sodium, and calcium, while the negatively charged ions (anions) are mostly chloride.



Impulse transmission in heart muscle cells

A living cell maintains a difference between the concentrations of the ions and charges within the cell and outside it. Typically, the inside of the cell has a higher concentration of potassium, while the outside environment has a higher sodium concentration. There is a negative charge within the cell as compared to outside because calcium, a positively charged ion, also floats outside the cell. The difference between electrical charges within and outside of the cell wall is considered as the cell's electrical potential. Because ions and chargers tend to maintain neutrality, sodium tends to enter the cell wall, and potassium tends to exit. In order to maintain its electrical potential, the cell has mechanisms that control these ions in ways that do not allow them to follow their natural tendency.

Phase 4 (Resting Potential)

The sodium-potassium ATPase pump facilitates the movement of ions around the cell to protect the electrical charge and concentration. It uses ATP to push out three sodium ions and pull in two potassium ions. This results in a more significant positive charge existing on the outside of the cell as compared to the inside. Because of this, the resting myocyte's electrical potential is maintained from between -70 to -90 millivolts.

After a while, the ions begin to overload the pump, and the cell's interior becomes less negative because more sodium ions are entering.

Threshold Potential

Gradually, the cell becomes positively charged, and this opens up a new batch of channels – the fast sodium channels. These are one-way valves that permit only ions such as sodium to enter the cell.

Phase 0

When these valves open, sodium ions rapidly enter the cell and cause a surge of positive charge inside it. This impulse stimulates the cell and passes on to the cells near it until all cells have been activated.

Depolarization

When the cell is no longer negatively charged or polarized, it is now said to be depolarized, and it is also positive, as the fluids outside it.

Phase 1

When the cell reaches its maximum positive charge, it enters phase 1 of the action potential. This triggers chloride ions (negative charge) to enter the cell, which slows down the entrance of sodium ions (positive control).

Phase 2

The rapid sodium channels close down at this point, while the slow sodium channels and the calcium channels open. The slow sodium channels let sodium ions slowly enter the cell, while the calcium channels let calcium enter. Since calcium has two positive charges, it helps maintain the cell's depolarized state.
Calcium helps cells contract by triggering actin and myosin proteins to move against each other. When there is more calcium, the proteins clamp faster and lease length.

Phase 3

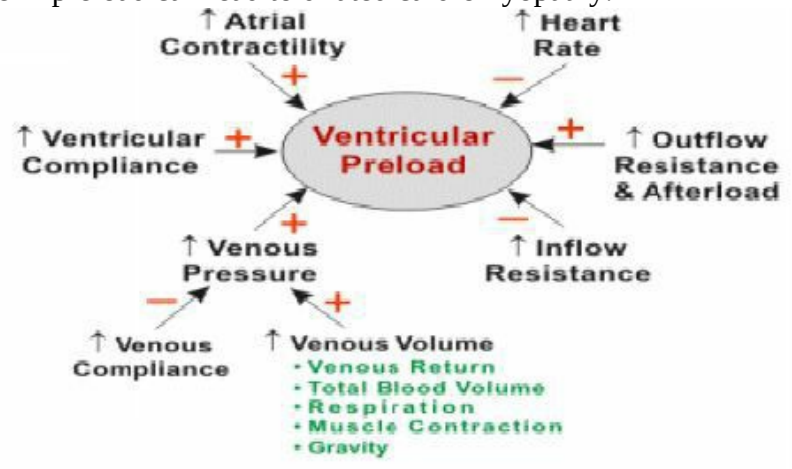
A few potassium channels open to make potassium ions exit the cell, causing rapid repolarization. The negative charge of the cell returns as positively charged potassium leaves it. This leads to the resting potential (phase 4), and the cycle begins again.
Each cell of the heart has these action potential cycles and can polarize and depolarize 70-100 times in one minute. Even though there are millions of cells in the heart, they all act together because of the electrical conduction system. These electrical discharges come together and create one large current or electrical axis. The ECG picks up these electrical potentials and transforms them into patterns.

Chapter 2. Physiology of the Heart

Concepts of Preload, Ejection Fraction, and Cardiac Output

Preload

Preload is the load on the ventricular muscle at the end of the diastole. It is determined mainly by the left ventricular end-diastolic volume and left ventricular end-diastolic pressure, in other words - by venous return.
The increase in preload will cause an increase in contractility, which subsequently leads to a rise in stroke volume and ejection fraction.
The increase in pulmonary capillary wedge pressure is evidence of increased preload. In mitral stenosis or mitral valve prolapse, it is not a useful index of left ventricular preload because of backward congestion leading to pulmonary edema.
A chronic increase in preload can lead to dilated cardiomyopathy.



Effects on the ventricular preload

Stroke Volume

Stroke volume is the amount of blood that heart pumps out with each beat. It is directly proportional to the contractility of the heart and inversely proportional to afterload.
Stroke volume is calculated as -
SV = EDV (End Diastolic Volume) – ESV (End Systolic Volume).

Ejection Fraction

Ejection fraction is the portion of blood that heart pumps out during one contraction, which is usually 60-70% in the healthy normal adult.
The ejection fraction is calculated as:
Ejection Fraction = stroke volume/end diastolic volume

Now, SV = EDV – ESV, and therefore, EF = EDV – ESV/EDV
For example, if the SV is 70 ml and EDV is 120 ml in 70kg man. Therefore, the ejection fraction is 60% in this individual.

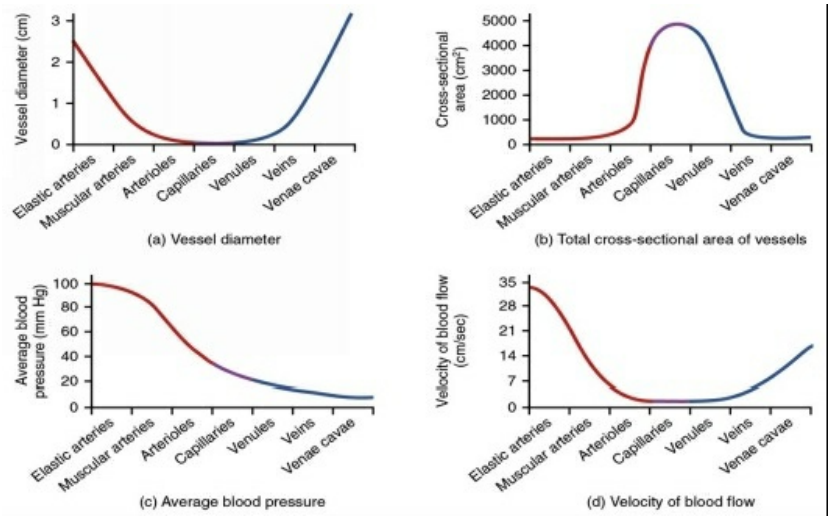
Cardiac Output

Cardiac output is the amount of blood that heart pumps out for 1 minute.
Cardiac output is calculated as CO = heart rate * stroke volume.
For example, If the heart rate is 72/min and stroke volume is 70 ml. Therefore, cardiac output in 1 minute = 5000ml or 5 L/min.
According to Fick's principle, CO = rate of oxygen consumption / arterial oxygen content – venous oxygen content.

Afterload

Afterload is the pressure against which the heart will work. It is determined by peripheral arterial resistance.
A chronic increase in afterload (e.g., hypertension, increasing age) will lead to left ventricular hypertrophy. Peripheral resistance is calculated as -
Blood flow = pressure/resistance (Q=P/R), therefore R = P/Q
Resistance is inversely proportional to the 4th power of the radius of the vessel.
If the resistance will increases, then the blood flow will decrease, and the heart will have to do more work to pump out blood against more resistance.
Chronically it will lead to systolic dysfunction (impaired contractility) and diastolic dysfunction (impaired ventricular relaxation).
Hypotension occurs when afterload is decreased (e.g., septic shock)

Concepts of Velocity, Area, Resistance, and Flow



Graphical representation of the vascular diameter, cross-sectional area, blood pressure, and velocity of blood flow*

The total cross-sectional area of capillaries is more than the aorta or vena cava.
The Aorta has the largest diameter but has the smallest total cross-sectional area.
The total flow is calculated as:
Flow = pressure/resistance or Q = P/R
Flow = cross sectional area * velocity of flow or Q = A*V or V = Q/A
Based on this equation, we can say that the velocity of flow decreases when the total cross-sectional area increases and vice versa.
Therefore, capillaries will have the least velocity of blood flow when compared to the aorta and vena cava because capillaries have the largest cross-sectional area.
Another formula to calculate flow across pulmonary vessels is -
Q = oxygen consumption / Po2 pulmonary vein – Po2 pulmonary artery
= 250 ml/min / 0.20ml/min – 0.15 ml/min = 5000 ml/min.

Auto-Regulation of Blood Flow

Autoregulation mechanism dominates over extrinsic mechanism (neuronal and hormonal influences). Because the gastrointestinal system does not have a dominant autoregulation system, their vessels will constrict under SNS activity, and therefore, blood flow decreases to the gastrointestinal system during exercise.

1. Coronary circulation: auto-regulated by endogenous adenosine and nitric oxide. When the heart is under stress, more ATP will be used up, and adenosine will form as a byproduct. Adenosine dilates coronary vessels and provides sufficient blood flow to the heart to meet its energy requirements.
2. Cerebral circulation: brain maintains its circulation mainly by arterial carbon dioxide level (PaCO2). During exercise, cerebral circulation is unchanged because exercise will increase the level of venous blood carbon dioxide level, which subsequently undergoes pulmonary oxygenation before reaching the brain.
3. Skeletal muscle (during exercise only): skeletal muscle during exercise regulates its blood flow with the help of myogenic stretch receptors (pressure-related) and vasodilator metabolites like lactate. In resting muscle, flow is controlled mainly by the sympathetic nervous system (alpha-1 and beta-2 receptors).
4. Renal blood flow: blood flow to the kidney is also commonly considered autoregulation even though neuronal and hormonal influences partially control it. During hypertension, renal afferents will constrict and maintain their blood flow to the kidney. Chronically, it will lead to hypertensive nephropathy.
5. Cutaneous blood flow: heat causes vasodilation, and cold temperature causes vasoconstriction. During fever and exercise, there is an increase in heat loss which causes flushing due to vasodilation.

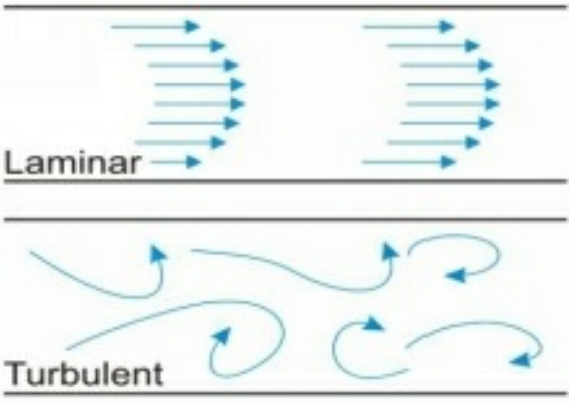
ORGAN SYSTEM	**CHANGE IN BLOOD FLOW DURING EXERCISE**
Coronary	Increases

Pulmonary	Increases
Cerebral	No change
Renal	Decrease
Gastrointestinal	Decrease
Exercising muscle	Increases
Cutaneous	Increases

Changes in blood flow to various organ systems during exercise

Laminar Flow and Turbulent Flow

Usually, we have laminar blood flow throughout the body except for the flow in the heart and conducting airways of a respiratory tree (due to excessive vessel branching).



Laminar flow and turbulent flow

The layer with the highest velocity is in the center of the vessels.

Heavier particles like inactivated neutrophils and platelets flow in the center of the vessel, while lighter particles flow at the periphery. This is because the center of flow will have the least resistance while the periphery will have maximum resistance.

Activation of cells like neutrophils or platelets due to endothelial injury or inflammatory process will pull them toward the periphery, and the 1st step of inflammation will occur.

Turbulent flow is a non-layered flow that creates a murmur. This can be heard as bruits in narrowed vessels (e.g., atherosclerosis of renal artery). The high velocity of blood flow can also create turbulent flow and can cause bruits (e.g., anemia).

Reynold's number can calculate the type of flow.

Reynold's number = diameter * velocity * density / viscosity

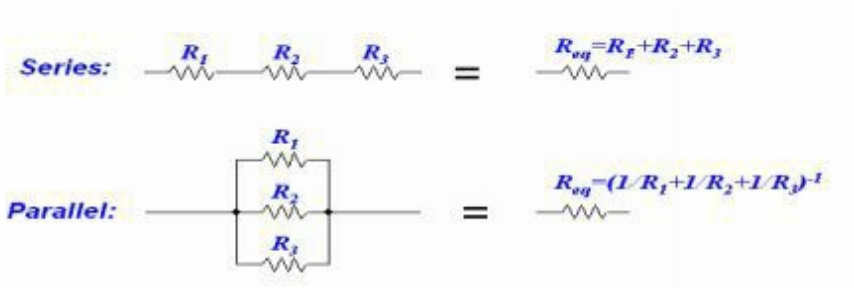
According to this formula, the diameter, velocity, and density of blood are directly proportional to turbulent flow, and viscosity is inversely proportional to turbulent flow. You do not need to remember specific numbers for the exam.

The increase in blood viscosity is seen in polycythemia, lung diseases (hypoxia-induced erythropoietin production from the kidney), multiple myeloma, and hereditary spherocytosis.

The decrease in blood viscosity is seen in anemia.

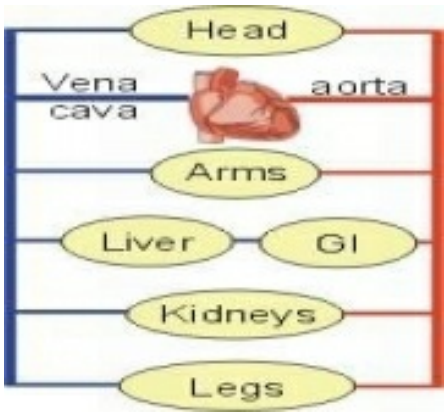
Resistance in Series and Parallel Circuits

Resistance is directly proportional to the viscosity of blood and length of the vessel, and it is inversely proportional to the 4th power of the radius.
R α viscosity * length /radius
It means when the radius of the artery decreases by ½ (50%), resistance will increase by 16 times (½* ½ * ½ * ½) and when the radius of the artery increases by ½ (50%), resistance will decrease by 16 times.
The increase in total peripheral resistance is the leading cause of primary hypertension worldwide. This accounts for 95% of hypertensive cases (4% is due to renal artery stenosis and 1% due to all other secondary causes of high blood pressure).
This is the reason, why many cardiac or antihypertensive pharmacological therapy is aimed to decrease total peripheral resistance.
Arterioles offer maximum resistance, and thus the steepest decrease in blood pressure will occur at this point.



Resistance in Series Circuit

It is calculated as the sum of all resistance: R1+R2+R3 = R (maximum).
An example of a series connection is aorta-intestinal vessels-liver-inferior vena cava. The total resistance will be higher than individual resistance.
When R2 is constricted, the pressure at R1 increases, and the pressure at R3 decreases. Clinically speaking, blood pressure distal to the narrowed point will be low (for example: In coarctation of the Aorta in adults, blood pressure will be higher in upper extremities when compared to lower extremities)
This concept can also be applied in pulmonary edema due to congestive heart failure. When the left heart fails to pump out blood (due to aortic stenosis, chronic hypertension, or myocardial infarction), hydrostatic pressure will increase in the pulmonary circulation, and extravasation of transudate (protein-free fluid) occurs in the lung interstitium, which will lead to one of the classic finding of the left heart failure - dyspnea.



Series connections (aorta-GI-liver-vena cava-heart-aorta) and parallel connections (head-arms-GI or liver-kidney-legs)

Resistance in Parallel Circuit

Resistance in a parallel circuit is calculated as the sum of the inverse of resistance: 1/R1 + 1/R2 + 1/R3 = 1/R (minimum).
An example of a parallel connection is pancreas-spleen-kidney-skin/bone.
Total resistance will be lower than individual resistance.
This concept can be applied in pregnancy, where the fetus is connected to the parallel circuit. Total peripheral resistance will decrease, which will indirectly increase cardiac output in pregnant. Blood pressure will not increase unless gestational hypertension develops.
This concept can also be applied in organ transplantation. When a donor donates his kidney, total peripheral resistance increases because the parallel circuit is removed. This will indirectly decrease cardiac output.
Coronary arteries have the most significant resistance, while pulmonary circulation has the least resistance.

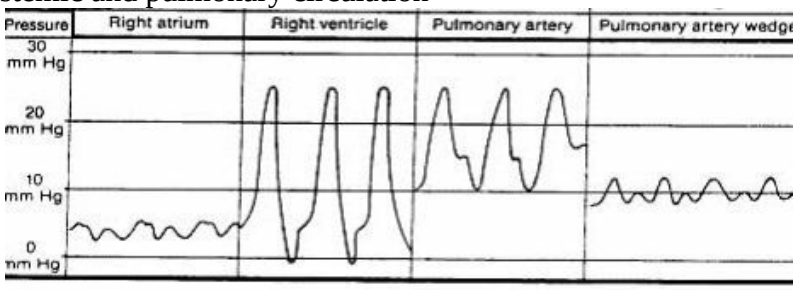
Blood Pressure

The primary factor that determines systolic blood pressure is stroke volume.
The increase in preload or increase in contractility will increase stroke volume, which will increase systolic blood pressure.
A decrease in compliance of vessels (age-related arteriosclerosis) also increases systolic blood pressure (isolated systolic hypertension).
The primary factor determining diastolic blood pressure is total peripheral resistance.

SYSTEMIC CIRCULATION (mmHg)		**PULMONARY CIRCULATION (mmHg)**	
Left ventricle	120/0	Right ventricle	25/0
Aorta	120/80	Pulmonary artery	25/8
Mean arterial pressure	93	Mean pulmonary artery pressure	15
Renal glomerular	50	Pulmonary capillary	7-10
Peripheral veins	15	Pulmonary veins	5

Right atrium (central venous pressure)	0-5	Left atrium	5-10
Pressure gradient	93-0 = 93	Pressure gradient	15-5 = 10

Pressure in the systemic and pulmonary circulation



Pulmonary pressure curve by the flow-directed catheter.

Mean Arterial Pressure

Mean arterial pressure is the average arterial pressure during the cardiac cycle.
It is calculated as MAP = cardiac output * total peripheral resistance.
MAP = 2/3rd diastolic pressure + 1/3rd systolic pressure.
If an individual has a blood pressure of 120/80 mmHg,
MAP = 2/3rd (80) + 1/3rd (120) = 92 mmHg
During static and high-intensity exercise like weightlifting, a physical compression of blood vessels raises total peripheral resistance. The increase in total peripheral resistance will increase blood pressure.
Dynamic and aerobic exercises will not significantly affect mean blood pressure (minor isolated systolic rise in blood pressure can be seen) because the decrease in total peripheral resistance (due to dilation of arterioles in exercising muscle) is accompanied by an equivalent increase in cardiac output.
Mean arterial pressure is not equal to mean systemic pressure.

Mean Systemic Pressure

Mean systemic pressure is the average pressure that exists in the vascular system if the cardiac output stops and the pressure within the vascular system redistributes.
It is an indicator of how full the circulatory system is.
The value of mean systemic pressure is nearly equal to right atrial pressure - 3-8mmHg.
Right atrial pressure is also called central venous pressure.
Mean systemic pressure depends on the total compliance of the arterial, venous beds and the total blood volume within them.

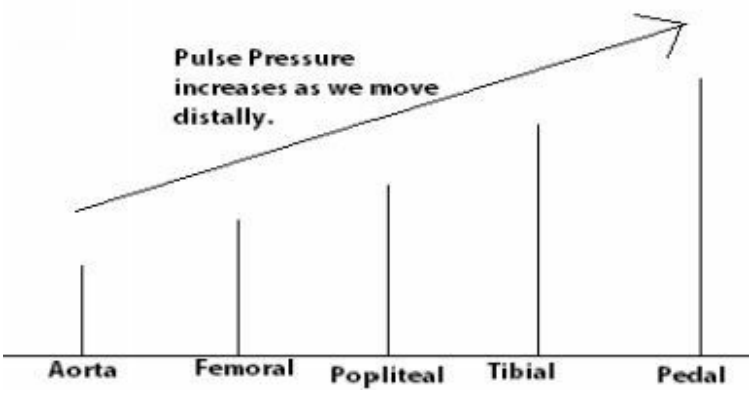
Compliance and Elasticity of Vessels

Compliance means the ability of the vessel to stretch (dilate). If the vessel is easily stretched, it is highly compliant.
Compliance is inversely related to elasticity.

Elasticity is the tendency to rebound back to its original size from a stretch.
A vessel with high elasticity will have low compliance.
Factors affecting compliance:
Endothelial dysfunction reduces compliance due to an increase in arterial stiffness.
This phenomenon is seen in hypertensive, diabetes, and smokers. Atherosclerosis will further aggravate this stiffness.
Pulse contour analysis is a non-invasive method of easily measuring arterial elasticity to identify patients at risk for cardiovascular problems. Age: Newborn will have higher compliant vessels compared to a 50-year-old man.
With the increase in age, compliance will decrease, and elasticity will increase. The less compliant artery will increase the total peripheral resistance that sometimes causes a pseudo-increase in blood pressure during blood pressure measurement in an elderly patient.
Fish oil alters vascular reactivity and positively influences arterial wall characteristics in patients with non-insulin-dependent diabetes mellitus. Venous compliance is approximately 25 times larger than arterial compliance and contains nearly 70% of systemic blood volume. Arteries are high-pressure vessels and are very stiff because of the high muscular layer, and therefore, arteries do not represent a significant blood reservoir. The Aorta is most compliant in the arterial system.
Compliance is calculated using the following equation, where ΔV is the change in volume, and ΔP is the change in pressure; $C = \Delta V / \Delta P$
Pulse pressure will increase while going distally from the Aorta (because compliance decreases). The pedal artery will have higher pulse pressure than the femoral artery, and the femoral artery will have higher pulse pressure than the Aorta.

Pulse Pressure

Pulse pressure is the difference between systolic pressure and diastolic pressure.
It is calculated as:
PP = systolic pressure – diastolic pressure.
Other factors that can widen pulse pressure are:
Increase in stroke volume (during exercise, systolic pressure increases more than diastolic pressure)
The decrease in vessel compliance (as we grow older, compliance decreases. Therefore, older people have higher pulse pressure compared to younger ones).
The compliant artery will have a small pulse pressure, and the stiffened artery will have significant pulse pressure.

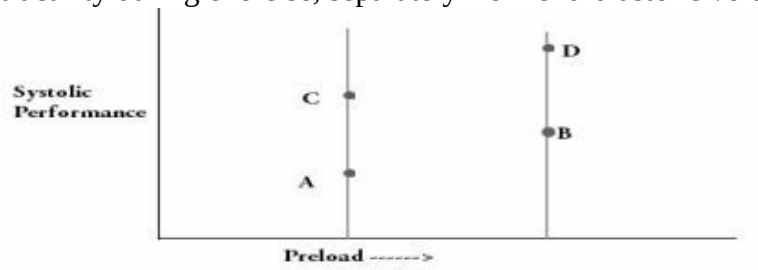


Pulse pressure change*

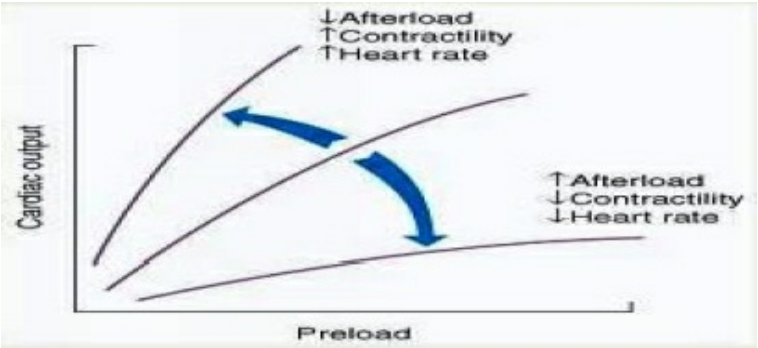
As we go distally from the heart, pulse pressure increases because diastolic blood pressure and compliance of vessel decrease.
This concept is applicable to arteries only because pulse pressure does not take into consideration of venous system.
If you are presented with any vein in multiple choices on an exam, do not select that answer because if calculated, veins will always have lower pulse pressure compared to arteries.

Relationship Between Contractility & Preload

The stroke volume of the heart increases in response to the rise in the volume of blood filling the heart (end-diastolic volume) when all other factors remain constant.
The increased volume of blood (preload) stretches the ventricular wall, causing the cardiac muscle to contract more forcefully. Stroke volume may also increase as a result of increased cardiac muscle contractility during exercise, separately from end-diastolic volume.



Performance change with the increase in preload and contractility*
Suppose point A is a normally functioning heart,
When preload is increased (e.g., on laying down), point A will move to point B. This increase in performance is entirely due to preload.
In response to increasing preload, a healthy heart will increase its contractility and shift point B to D. Therefore, an increase in performance from point A to point D is a combined effect of preload and contractility (e.g., exercise).
If contractility is independently increased (e.g., digoxin, dobutamine), it would shift the heart performance from point A to point C. Thus, point A to C is entirely due to an increase in contractility.



Effects of preload, afterload, contractility, and heart rate on cardiac output*
When the line shifts to the left (upward), contractility increases, and when the line shift to the right (downward), contractility decreases.
Various positive inotropic drugs like digoxin, catecholamine, and exercise will cause an increase in contractility.

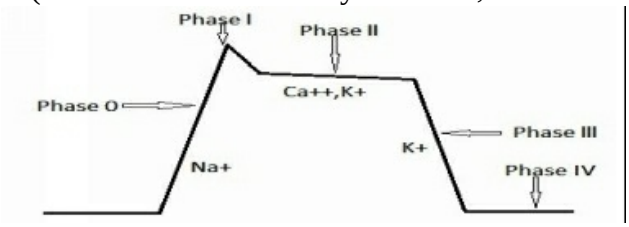
Chapter 3. Definitions

Depolarization and Repolarization

Cells are electrically stimulated, followed by mechanical contraction of the myocardium.
Return of the cell's membrane potential to a resting state following depolarization. The chambers are relaxed and re-filling in preparation to eject blood during the next contraction.
All cardiac cells are electrically polarized in their resting state; that is, they have a negative resting internal charge with respect to their outsides. This negative resting internal charge is maintained by membrane pumps that ensure sufficient negatively charged ions are kept within the cells.
Depolarization and repolarization refer to the change in the electrical charge. Depolarization is the process in which cardiac cells lose their negative internal charge. Depolarization flows from cell to cell, stripping the cells of their resting polarity, which produces a wave of depolarization that is represented on the EKG.
The cells become repolarized once the electrical conduction has come to an end. During repolarization, the cardiac cells regain their internal negativity, thereby restoring their resting polarity. This electrical activity is also recorded on the EKG.
This electrical activity that passes through the heart is represented on the EKG by the P wave, the QRS complex, and the T wave.

Action Potential

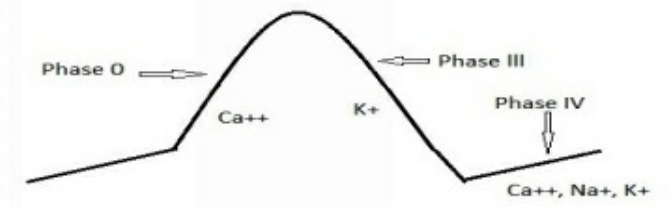
Particular types of voltage-gated ion channels are embedded in a cell's plasma membrane, which generates an action potential. They handle the generation of electrical impulses in the heart.
Fast response fibers (atrial and ventricular myocardium, His-Purkinje system)



Cardiac action potentials in fast response fibers
Resting membrane potential is the voltage difference between the inside of the membrane and outside of the membrane.
The intracellular environment of the cell has negative RMP (-90mV). When the cell is appropriately stimulated, positive charges such as sodium and calcium will go into the cell and increase the RMP. When the membrane potential reaches its threshold (-70mV), the voltage-gated sodium channels open, and a rapid influx of sodium (positive ions) occurs, which will increase the membrane potential to +10mV. This event is called depolarization **(phase 0).**
Class I antiarrhythmic like procainamide blocks phase 0 in fast response fibers.
Phase 1 is called overshoot and clinically insignificant. Sodium channels are inactivated during this phase. Overshoot develops because of slow potassium current going out of the cell and chlorine coming into the cell. No drugs act on this phase.
After the cell is depolarized, depolarized-sensitive calcium and potassium channels start opening.

The level of intracellular potassium (positive charge ion) is higher than extracellular potassium, and the level of extracellular calcium (positive charge ion) is higher than intracellular calcium. For a brief duration, potassium is going out, and calcium is coming into the cell and keep balance in the electromagnetic voltage across the cell membrane **(phase 2).**
As time passes, a delayed-rectified potassium channel opens, and heavy efflux of potassium occurs from the intracellular to the extracellular environment, and RMP returns back to -90mV (due to concentration-dependent efflux of positive ions). This phenomenon is called repolarization **(phase 3).**
After the repolarization phase, **the** Na+/K+ ATPase pump will send two sodium ions out of the cell in exchange for three potassium ions. This will help to increase ion concentration inside and outside the cell **(phase 4).**
This whole process of depolarization and repolarization is called the action potential. When the cell is undergoing depolarization, some of these sodium ions will go to the next cell via gap junction, and resting membrane potassium reaches the threshold of the adjacent cell and leading to its depolarization and repolarization. This cell will stimulate another adjacent cell, and the action potential passes over the entire myocardium.

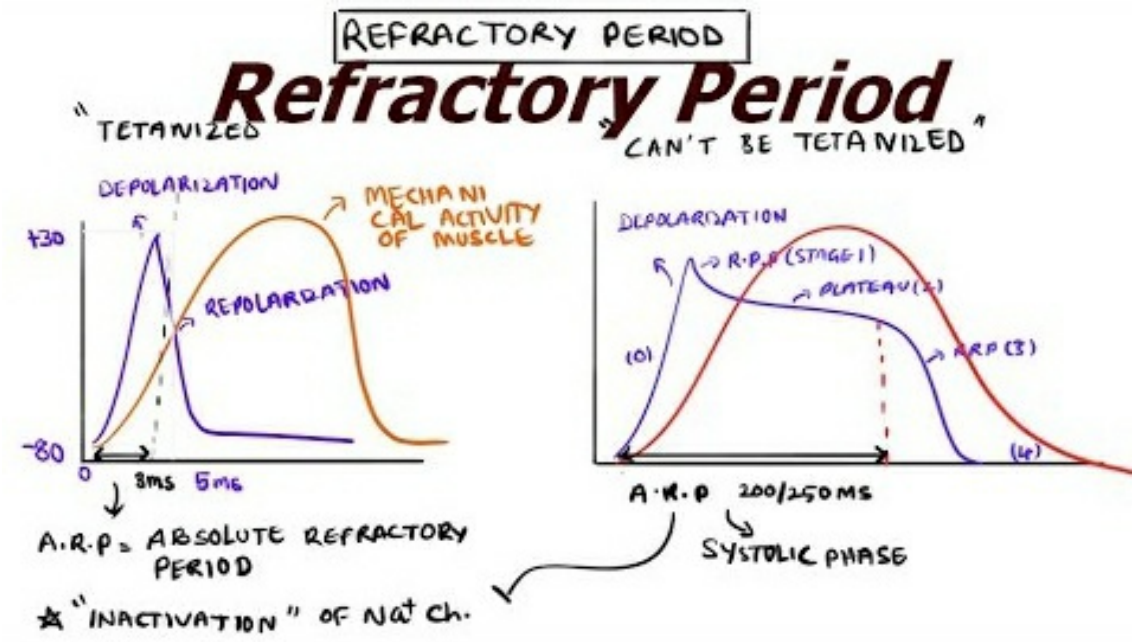
Action potential in slow response fibers (SA and AV nodes)



Cardiac action potentials in slow response fibers

- **Phase 0 (depolarization phase):** this phase depends on the calcium channels and not on the sodium channels. With each depolarization, the SA node will send signals to contract the heart. Class IV antiarrhythmic like verapamil and diltiazem will slow down this phase.
- Phase I & II is not present **in SA and AV node**
- **Phase III** (repolarization phase): this phase mainly depends on potassium going out of the cell.
- **Phase IV (raising slope):** this phase is also referred to as pacemaker current. It is mainly due to the inward sodium-calcium currents and outward potassium currents. The parasympathetic nervous system, beta-blockers, and calcium channel blockers act on this phase and decrease the heart rate.

Refractory Period



Chapter 4. Blood Pressure

Hypertension

High blood pressure is said to be present if it is persistently at or above 140/90 mmHg in adults. The higher number corresponds to systolic pressure, while lower numbers correspond to diastolic pressure.
Decisions about the aggressiveness of treatment are made according to the classification.
Prehypertension is not considered abnormal. However, advise your patient for lifestyle modifications.
Primary (essential) and secondary hypertension -

- Primary (essential) hypertension is most common (95% cases). It is diagnosed when there is no identifiable secondary cause.
- Secondary hypertension is diagnosed when hypertension is due to some underlying secondary cause (5-8% cases).

PATHOGENESIS

1. Systolic Blood Pressure (SBP)

SBP correlates with stroke volume and the compliance of the Aorta.

- Stroke volume is directly proportional to the contractility of the heart. An increase in the contractility of the heart will cause an increase in cardiac output.
- Compliance of vessels decreases with age because of reduced elasticity of the Aorta. The decrease in compliance of arteries is the mechanism for systolic hypertension in an individual >60 years of age.

- Systolic blood pressure will rise with an increase in preload, contractility, and a decrease in compliance of the Aorta and vice versa.

2. Diastolic Blood Pressure (DBP)

DBP correlates with the volume of blood in the Aorta during diastole. Diastolic blood pressure will rise with an increase in peripheral vascular resistance, blood viscosity, and heart rate.

- DBP increases with vasoconstriction of the arterioles due to the increase in the volume of blood present in the artery during diastole.
- An increase in blood viscosity is seen in polycythemia, leukemia, dehydration, while the decrease in blood viscosity is seen in anemia, hyper-hydration.

Etiology

Primary hypertension: the most common cause of hypertension is essential hypertension (95% cases of hypertension).

- Environmental or genetic cause.
- Stress: people under stress may overeat or eat a less healthy diet, put off physical activity, drink, smoke, or misuse drugs, which also leads to the release of stress hormones in circulation.
- High alcohol intake.
- Insulin resistance: common in obesity and is a component of metabolic syndrome'.
- Premature baby (low birth weight), maternal smoking and lack of breastfeeding, chewing tobacco, elevated LDL.
- Obesity and lack of exercise: Excessive weight will increase strain on the heart, raises blood cholesterol and triglyceride levels. It will also increase the risk of diabetes. Losing as little as 10 to 20 pounds can help lower your blood pressure and your heart disease risk.
- Age= greater than 55 years for men or greater than 65 years for women.

Secondary Hypertension: occurs due to pre-existing pathology:

1. **Renal disease (3-5% cases)**
    - Polycystic kidney disease: multiple cysts in the kidney.
    - Fibromuscular dysplasia (most common in younger females): it is a developmental defect of the blood vessel wall that results in irregular thickening of large and medium-sized arteries and thus causing a stenosis-like condition.
    - The renal artery is most commonly affected, which will reflexively cause

activation of the renin-angiotensinogen system. Bruits can be heard due to renal artery stenosis.

- Doppler ultrasound can be used for diagnosing renal artery stenosis. The most accurate is an angiogram. Treatment is renal artery angioplasty and stenting.
- Chronic kidney disease: glomerulonephritis, diabetic nephropathy.
- Urinary tract obstruction: kidney stones, Proteus infection (struvite stones), congenital malformations, and other conditions that can obstruct the outflow.
- The renin-producing tumor will lead to high levels of renin.
- It is treated with a combination of a low sodium diet and potassium-sparing diuretic drugs.

2. Endocrine conditions (1-2% cases)

- Cushing's syndrome: high level of mineralocorticoids.
- Hypothyroidism
- Pheochromocytoma: tumor of the adrenal medulla which causes the episodic hypertensive crisis.
- Neuroblastoma: high level of catecholamine.
- 11-hydroxylase deficiency: high level of deoxycorticosterone (acts like aldosterone) and sex hormones (hirsutism).
- Acromegaly: increase in growth hormone level in adulthood.
- Conn's syndrome: primary hyperaldosteronism resulting in hypokalemia.

3. Vascular conditions

- Increasing age: systolic hypertension due to decreased elasticity of the Aorta in the elderly population.
- Coarctation of the Aorta: narrowing in the arch of the Aorta will cause high blood pressure in the upper extremities and low blood pressure in the lower extremities. This results in under perfusion of the kidney resulting in activation of the RAS system.
- Vasculitis: inflammation of vessels (increases total peripheral resistance by narrowing vessels).
- Collagen vascular disease: occurs when problems with the immune system affect the collagen. This causes arthritis and inflammation of arteries in the tissues that connect joints and other tissues. It can be seen in ankylosing spondylitis (HLA-B27 serotype), dermatomyositis, rheumatoid arthritis (HLA-DR 3, HLA- DR 4 serotype), SLE, and other immune-mediated diseases.

4. **Oral contraceptives:** activates the renin-angiotensinogen system because the hepatic synthesis of angiotensinogen is induced by the estrogen component of oral contraceptives. The best way to manage this cause of hypertension is to stop the use of oral contraceptives, and hypertension goes away in 6 months.
5. **Exogenous steroids:** increases blood pressure by volume expansion.
6. **NSAIDs**: blocks both cyclooxygenase-1 (COX-1) and COX-2 enzymes. COX-2 has a natriuretic effect. The inhibition of COX-2 can inhibit its natriuretic effect. NSAIDs also inhibit the vasodilation effects of prostaglandins at renal afferents and produce vasoconstriction factor (endothelin-1).
7. **Smoking:** causes vasoconstriction and damages arteries leading to atherosclerosis, thromboangiitis obliterans, Raynaud's phenomenon.
8. **Pregnancy:** gestational hypertension (new-onset hypertension that develops after 20^{th} week of pregnancy), pre-eclampsia (hypertension + proteinuria) or eclampsia (hypertension + seizures)

Clinical Presentation

Hypertension is usually an asymptomatic condition.
Headache is not a reliable symptom of hypertension. Other findings that might be present in chronic hypertension are:

- Fatigue, confusion, and vision problems
- Chest pain and difficulty breathing
- Blood in the urine
- Pounding in your chest, neck, or ears
- Symptomatic nosebleeds (nose picking is the most common cause of nosebleeds)

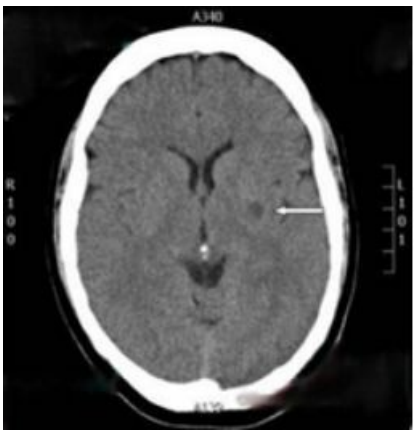
A variety of symptoms may be indirectly related to hypertension but are not always caused by it, such as:

- Blood spots in the eyes or subconjunctival hemorrhage, facial flushing, and dizziness

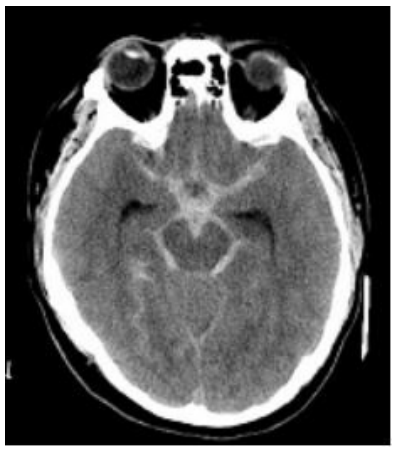
Complication

- Left ventricular hypertrophy (most common overall complication)
- Acute myocardial infarction (a most common cause of death)
- Atherosclerosis
- Intracerebral hematoma (due to rupture of Charcot-Bouchard aneurysms)
- Subarachnoid hemorrhage (due to rupture of a berry aneurysm)

- Lacunar infarcts (small infarcts due to hyaline arteriolosclerosis). Typical location of lacunar infarcts includes basal ganglia, pons, internal capsule, thalamus, and cerebral white matter.



Lacunar infarct of putamen*



Subarachnoid hemorrhage*

- Benign nephrosclerosis (atrophy of tubules and sclerosis of glomeruli occurs due to hyaline arteriolosclerosis)
- Malignant hypertension (rapid increase in blood pressure accompanied by renal failure and cerebral edema)
- Hypertensive retinopathy (arteriovenous nicking, hemorrhage of retinal vessels, retinal infarction, papilledema)

Management

- Lifestyle modification is always the first step in the management of hypertension. It is usually recommended for 3-5 months for mild hypertension. Start medical therapy if not controlled.
- The goal of hypertension control in **diabetic hypertensive** or patients under the age of 60 **is 140/90 mmHg**. The goal of hypertension **in age greater than 60 is 150/90 mmHg.**
- The goal of antihypertensive therapy is the reduction of cardiovascular and renal morbidity and mortality, with the focus on controlling the systolic blood pressure. Most patients will achieve diastolic pressure control when the systolic blood pressure control is achieved.
- Body mass index (BMI) should be reduced to 25 kg/m2, and waist circumference should be reduced to less than 88 cm in women and less than 102 cm in men. Decreasing the BMI is the most effective way of lifestyle modification and management of hypertension.
- The patient is advised to do regular aerobic exercises and follow relaxation techniques like yoga.

- Ambulatory blood pressure monitoring should be incorporated.
- Diuretics like thiazides are the first line of drug for the management of hypertension, with some exceptions:

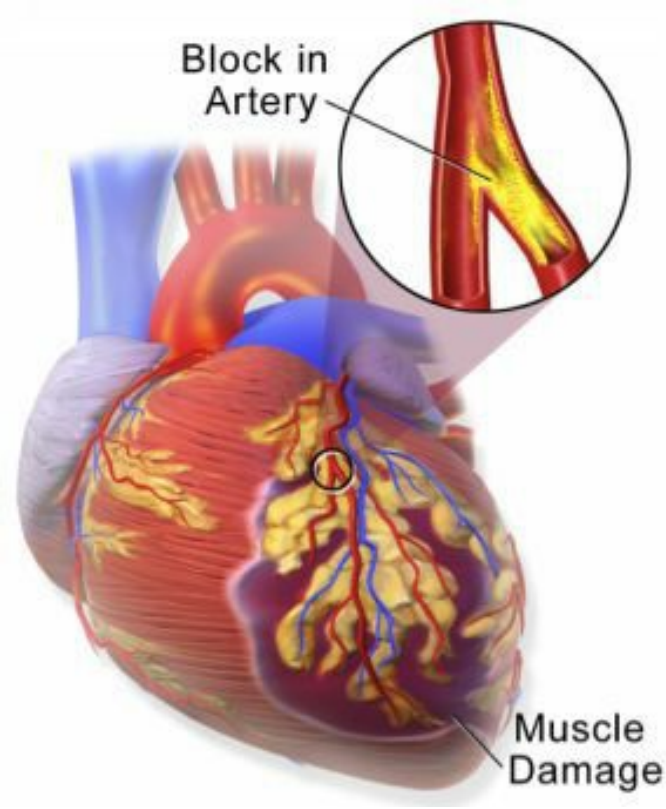
  Diabetics: ACE inhibitors are the first line of drug
  Benign prostatic hyperplasia: alpha-blockers
  Migraine headache: beta-blockers, calcium channel blockers
  Pregnancy: labetalol, methyldopa, hydralazine (for acute reduction)

- If the two drugs combination fails to control blood pressure, add a 3rd drug. Suspect secondary hypertension if 2 or 3 drugs fail to control primary hypertension.
- Although additional data are needed, renal denervation is a promising therapy in the treatment of resistant hypertension.

Chapter 5. Notes on Blood

Myocardial Ischemia and Infarction

Ischemia: Ischemia is the restriction in blood supply to the tissues, which results in decreased blood flow and tissue hypoxemia. This decrease in blood flow causes delays in the heart's depolarization and repolarization pattern. If ischemia spreads across the entire thickness of the ventricular wall, there is an imminent danger of myocardial infarction.
Infarction: Infarction is the complete obstruction of one of the coronary arteries, which restricts a tissue's blood supply, thereby causing a lack of depolarization tissue death.

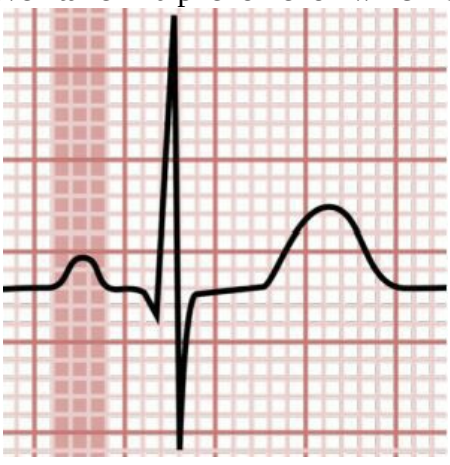


I. Using EKG to Diagnose an Evolving Ischemia and Infarction

There are several stages of ischemia and infarction that can be traced on EKG. In this part, we will cover the three main changes of an evolving infarction that are visible on EKG:

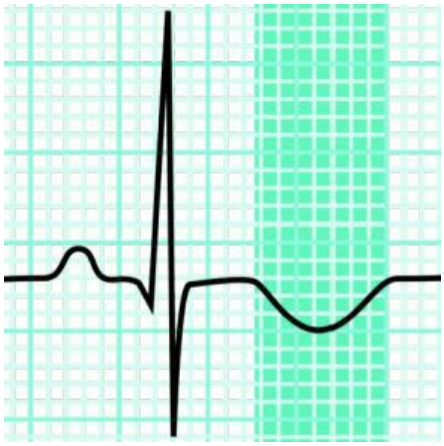
1. *T wave which peaks and then inverts*: An **inverted T wave** is associated with the initial stages of Ischemia.

The diagram below shows a normal T wave that is tall and upright in shape. With the onset of infarction, the T wave becomes even taller – a phenomenon which is called 'peaking.'



A couple of hours later, the T wave inverts in the same patient. The diagram below shows an inverted T wave. These changes in T waves are representative of ischemia – a lack of adequate

blood flow to the heart muscle.

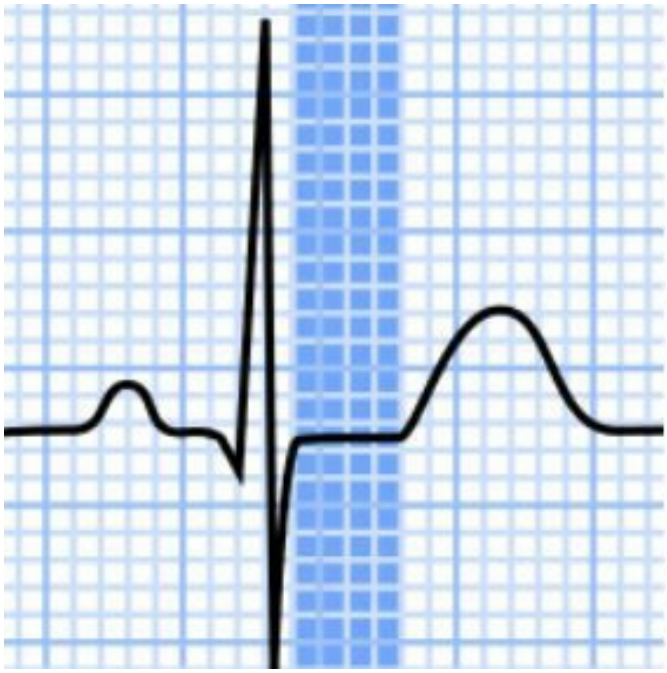


It is important to note that the inverted T wave is the only representative of ischemia and is not per se diagnostic of infarction. On top of this, there are other conditions that can cause an inverted T wave, such as bundle branch blocks.

2. ST-segment depression, followed by an ST-segment elevation.

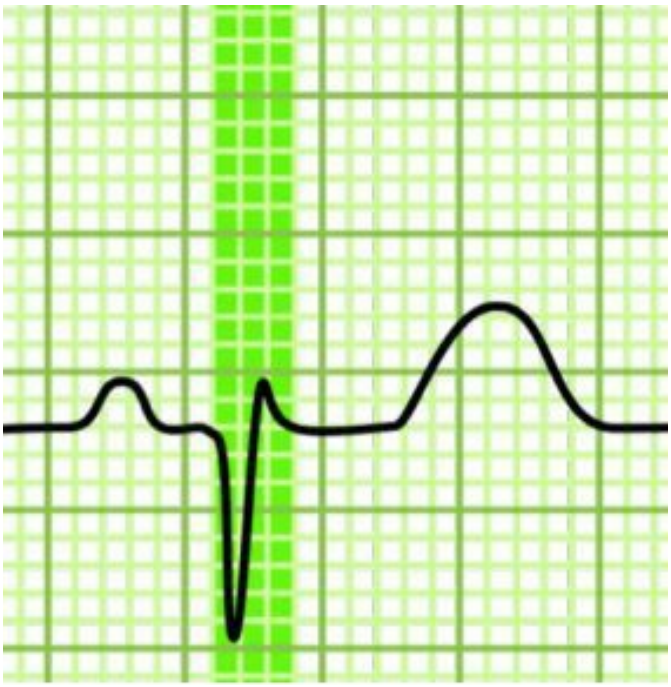
- **ST-segment depression** will be visible on EKG as the ischemia extends into the deeper layers of the myocardium – **ST depression is an indicator that an infarction may be imminent.**
- **ST-segment elevation** reflects myocardial injury. Height of the ST segment above the baseline is called the **injury pattern** and is representative of early-stage infarction. It is suggestive of cellular damage beyond ischemia.

The ST segment is the horizontal baseline immediately before the T wave. The diagram below shows a normal ST-segment on EKG, which is highlighted by the vertical strip. In general, depression or elevation with a deflection of 2 small boxes or more should be considered clinically significant.



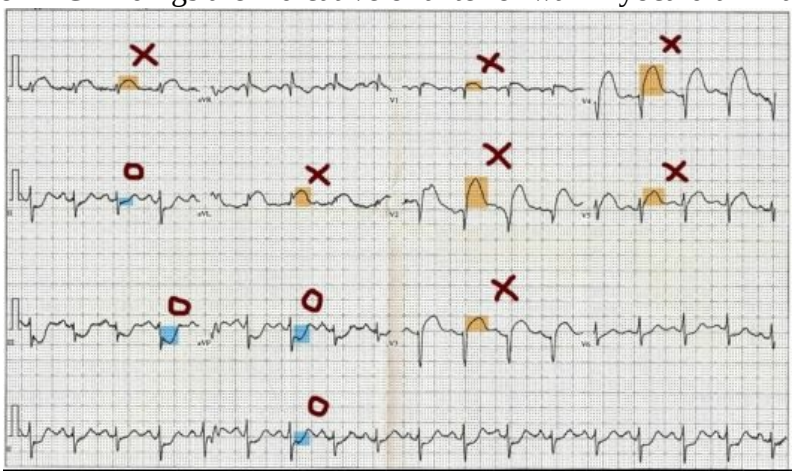
3. Q wave/the first downward deflection after the P wave is indicative of an infarction.

The appearance of new Q waves is an indication of infarction. By this time, the ST segment has usually returned to the baseline.



The new Q waves tend to persist forever in clients who have suffered from myocardial infarction. Scar tissue after myocardial infarction does not depolarize. Because of this, once an area of the myocardium has died, it becomes electronically silent. Electrical vectors will then point away from this area. Any electrodes overlying the dead tissue will record a deep negative

deflection. On EKG, therefore, infarctions are presented by negative forces, that is, Q waves and inverted T waves (as highlighted in the diagram above).
Leads that are located near the infarction site will experience an increase in electrical activity that is directed toward them. These leads will record positive and tall R waves. These opposing changes, which are called **reciprocal changes**, are recorded by distant leads. These distant leads will record an ST-segment depression.
On the EKG strip below, the highlighted sections marked with an X show ST-segment elevation in Leads I, aVL, and V1 to V5 with reciprocal changes (highlighted and marked with O) in the inferior leads. These EKG findings are indicative of anterior wall myocardial infarction.

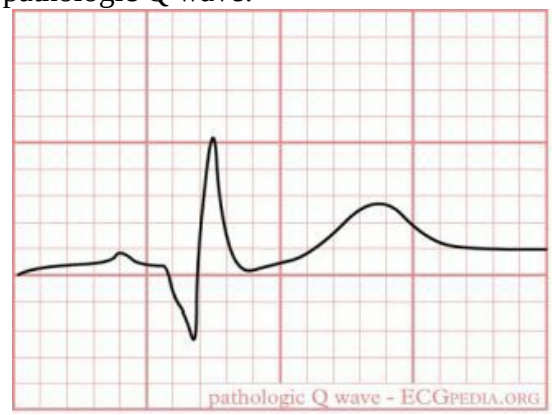


II. Normal Vs. Pathologic Q Wave

In normal hearts, a small Q wave can be seen in the left lateral leads and sometimes also in the inferior leads. In comparison, pathologic Q waves, which are indicative of infarction, are wider and deeper in form. Because of this, they are often referred to as **significant Q waves.** In general, the EKG criteria for pathologic Q waves include the following:

- A Q wave which is longer than 0.04 seconds in duration (i.e., longer than one small box on EKG paper).
- The depth of the Q wave is at least one-third the height of the R wave in the same QRS complex.

The diagram below shows a pathologic Q wave:



III. Locating the Infarct

When diagnosing ischemia or infarction, it is essential to follow a pattern: begin by examining the inferior leads, the lateral leads, and then the anterior leads. Analyzing them in their groups is necessary for terms of helping you narrow down the focus of the affected area. Also, recall which main coronary artery supplies this section.

Leads	Group
Leads V1, V2, V3, V4	Anterior chest leads
Leads I, aVL, V5, V6	Left lateral leads
Leads II, III, aVF	Inferior leads
Lead aVR	-

It is important to note that if, for example, there is a Q wave in Lead II but not in Lead III and Lead aVF, this should be interpreted as a 'non-specific finding.' It cannot be diagnostic of an old inferior wall myocardial infarction because for a diagnose of ischemia or infarction, and there have to be changed in all contiguous leads.

When diagnosing ischemia or infarction, reciprocity is also something that should be kept in mind. The injury itself will be represented by ST elevation. The reciprocal change, therefore, will take the form of ST depression. To help confirm the diagnosis, it is again helpful to examine the leads as individual groups and to note the following:

- Reciprocal changes in the inferior leads are indicative of anterior wall injury and/or later wall injury.
- Reciprocal changes in the lateral leads are indicative of inferior wall injury.
- Reciprocal changes in the anterior leads are indicative of posterior wall injury.

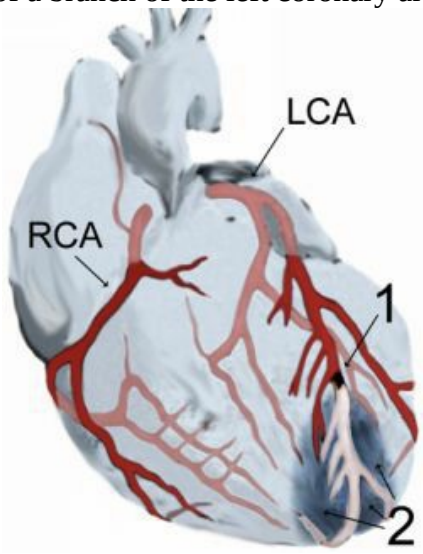
Infarctions are grouped into several categories depending on the site of the infarct and include anterior infarctions, inferior infarctions, lateral infarctions, and posterior infarctions.

ANTERIOR WALL ISCHEMIA & INFARCTION

Blood to the anterior myocardium is supplied by the left anterior descending artery. Ischemia affecting this area can be diagnosed by examining the T waves and the ST segments in the precordial chest leads (**Leads V1 to V4**). The following EKG characteristics are indicative of ischemia affecting the anterior wall:

- **Reciprocal changes** in the inferior leads (leads II, III, and aVF).
- Early-stage ischemia is reflected by a **T wave inversion** in leads V1 to V4.
- Progressing ischemia is reflected by an **ST-segment depression** in Leads V1 to V4.
- Ongoing injury is reflected by **ST-segment elevation** in Leads V1 to V4.
- Transmural infarction is reflected by **Q waves** in Leads V1 to V4.

The diagram below shows a myocardial infarction (labeled 2) of the anterior wall. This was caused by a blockage (labeled 1) of a branch of the left coronary artery (LCA).



INFERIOR WALL ISCHEMIA & INFARCTION

Blood to the inferior myocardium is supplied by the RCA. An infarction in the inferior wall of the heart is commonly caused by an occlusion of the RCA or its descending branch. Ischemia affecting this area can be diagnosed by examining the T waves and the ST segments in the inferior leads (**leads II, III, and aVF**). The following EKG characteristics are indicative of ischemia affecting the inferior wall:

- **Reciprocal changes** in the left lateral leads (Leads I, aVL, V5, and V6).
- Early-stage ischemia is reflected by a **T wave inversion** in Leads II, III, and avF.
- Progressing ischemia is reflected by an **ST-segment depression** in Leads II, III, and avF.
- Ongoing injury is reflected by **ST-segment elevation** in these leads.
- Transmural infarction is reflected by **Q waves** in the same leads.

Because the RCA also supplied the AV node, a complete heart block (third-degree heart block) is sometimes also associated with acute inferior wall infarction. Myocardial infarction in the inferior wall will often also result in left axis deviation with the electrical vectors pointing away from the infarct.

LATERAL WALL ISCHEMIA & INFARCTION

Blood to the lateral wall is supplied by the left circumflex artery. Ischemia affecting this area can be diagnosed by examining the T waves and the ST segments in the left lateral leads (**Leads I, aVL, V5, and V6**). The following EKG characteristics are indicative of ischemia affecting the lateral wall:

- **Reciprocal changes** in the inferior leads (leads II, III, and aVF).
- Early-stage ischemia is reflected by a **T wave inversion** in Leads I, aVL, V5, and V6.

- Progressing ischemia is reflected by an **ST-segment depression** in Leads I, aVL, V5, and V6.
- Ongoing injury is reflected by **ST-segment elevation** in these leads.
- Transmural infarction is reflected by **Q waves** in the same leads.

Myocardial infarction in the lateral wall will often also result in right axis deviation because electrodes point away from the area of injury (which has become electronically 'silent').

POSTERIOR WALL ISCHEMIA & INFARCTION

An infarction in the posterior wall is rarely seen alone. Posterior wall infarction is most observed in the presence of inferior or lateral wall infarction. Blood to the posterior wall is supplied by either the RCA or the left circumflex area (depending on which of the two supplies the majority of the posterior wall). Diagnosing ischemia in this area is significantly more difficult because the placement of the leads in the classic 12-lead EKG does not provide a good view onto the posterior wall of the heart. As a result of this, we have to rely on reciprocal changes in the diagnosis of posterior wall ischemia and infarction.

Depolarization of the posterior wall is the exact opposite of depolarization of the anterior wall. Because of this, diagnosing ischemia affecting the posterior wall is made by looking at the reciprocal changes in the anterior chest leads. **Anterior wall** infarction can be diagnosed by identifying an ST-segment elevation and Q waves in the anterior chest leads (**Leads V1, V2, V3, and V4).** Ischemia in the posterior wall will produce a mirror image.' The following EKG characteristics are indicative of ischemia affecting the posterior wall of the heart:

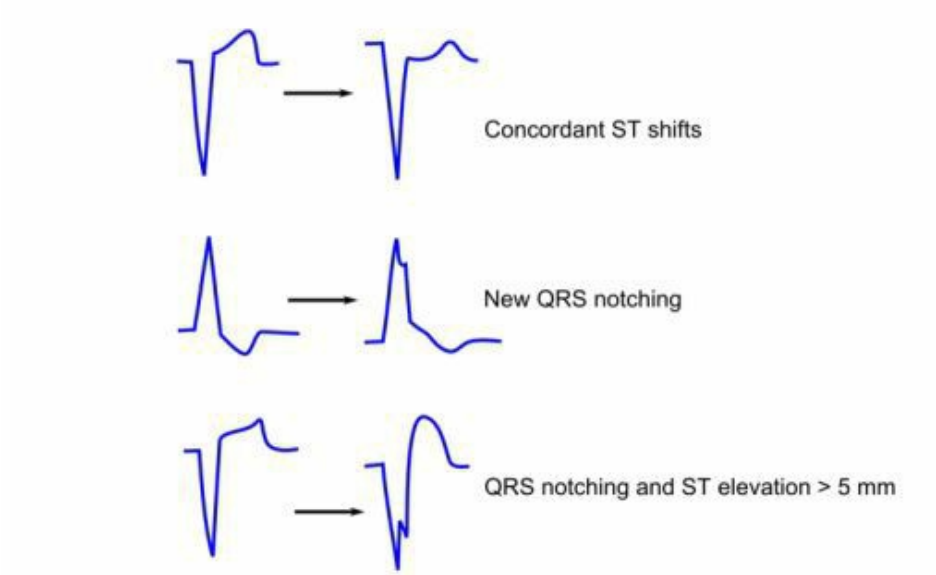
- Posterior wall ischemia is reflected by **tall R waves and ST-segment depression** in the anterior leads (Leads V1 to V4).
- Progressing ischemia is reflected by the development of **larger S waves and smaller R waves** in Leads V1 to V4.

IV. EKG Limitations & Sgarbossa's Criteria

As covered above, a typical diagnosis of an evolving myocardial infarction includes ST-segment changes as well as the appearance of a new Q wave. An underlying cardiac condition can, however, distort EKG findings, which makes the diagnosis by way of EKG interpretation unreliable. Right bundle branch blocks (RBBBs) do not usually alter EKG findings of ischemia or infarction. Left bundle branch blocks (LBBBs), on the other hand, affect both phases of ventricular depolarization and are thereby represented by Q waves, St segment, the loss of normal R wave progression, as well as T wave changes. All these EKG findings can also be present in ischemia and infarction. Nevertheless, there are specific criteria that can be used to diagnose ischemia or infarction in the presence of LBBB.

Sgarbossa's criteria are a set of EKG findings that can be used to diagnose a suspected infarction in the presence of an LBBBs or ventricular-paced rhythm.

It is important to note that although these criteria are sensitive, they are not specific for myocardial infarction. A total score of > 3 is said to have a specificity of 90% for diagnosing infarction.



Chapter 6. EKG

What is the EKG?

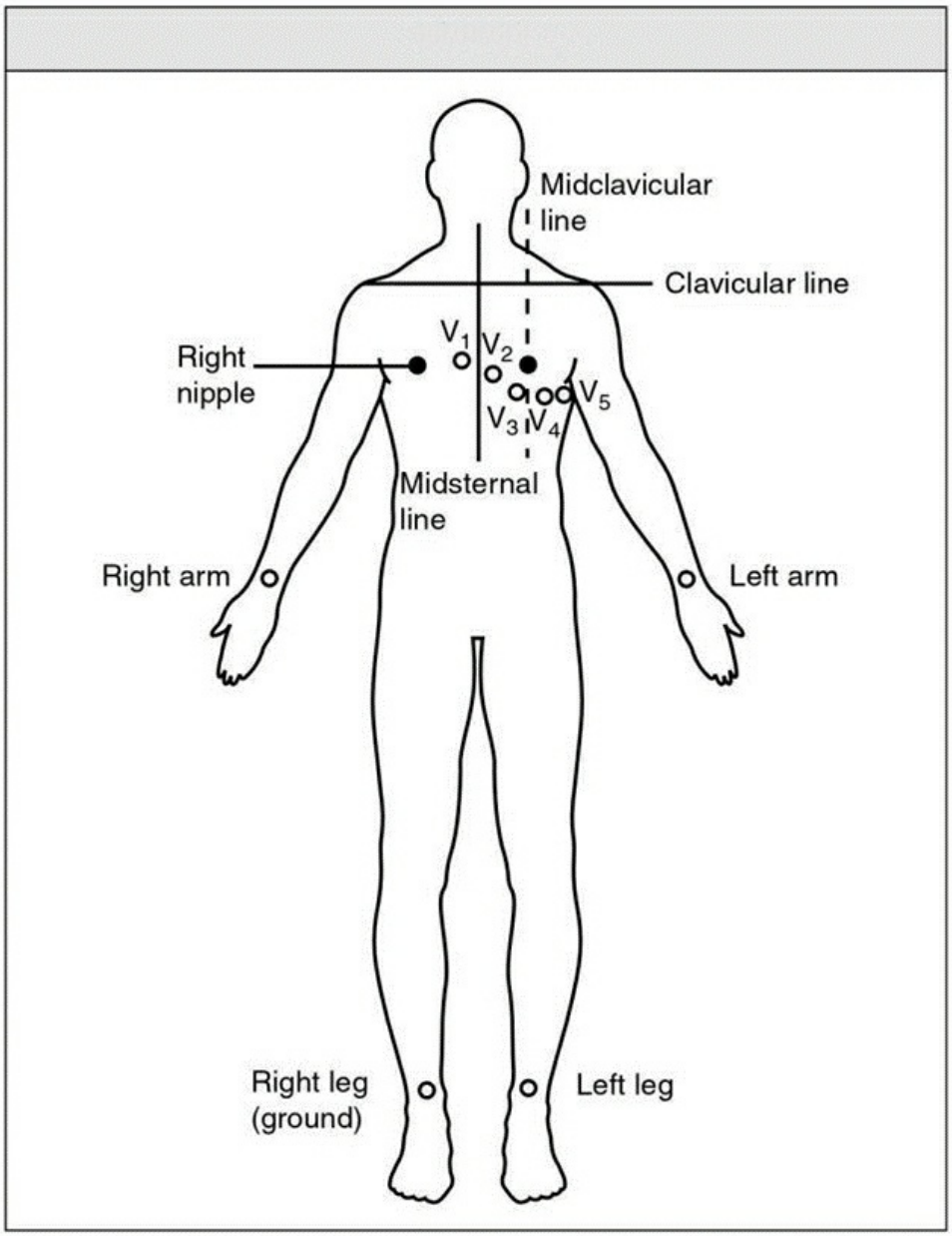
Basically, electrocardiography (abbreviated EKG or ECG) refers to the tracings of the electrical activities of the heart. With electrocardiography, the clinician can study the electrical activities that go on in the heart. This is done by placing electrodes over the skin. These electrodes can then pick up those small electrical changes generated from the myocardium to the skin surface. It is important to note that this low-intensity current flows through the body, which acts as a volume conductor.

What Is It For?

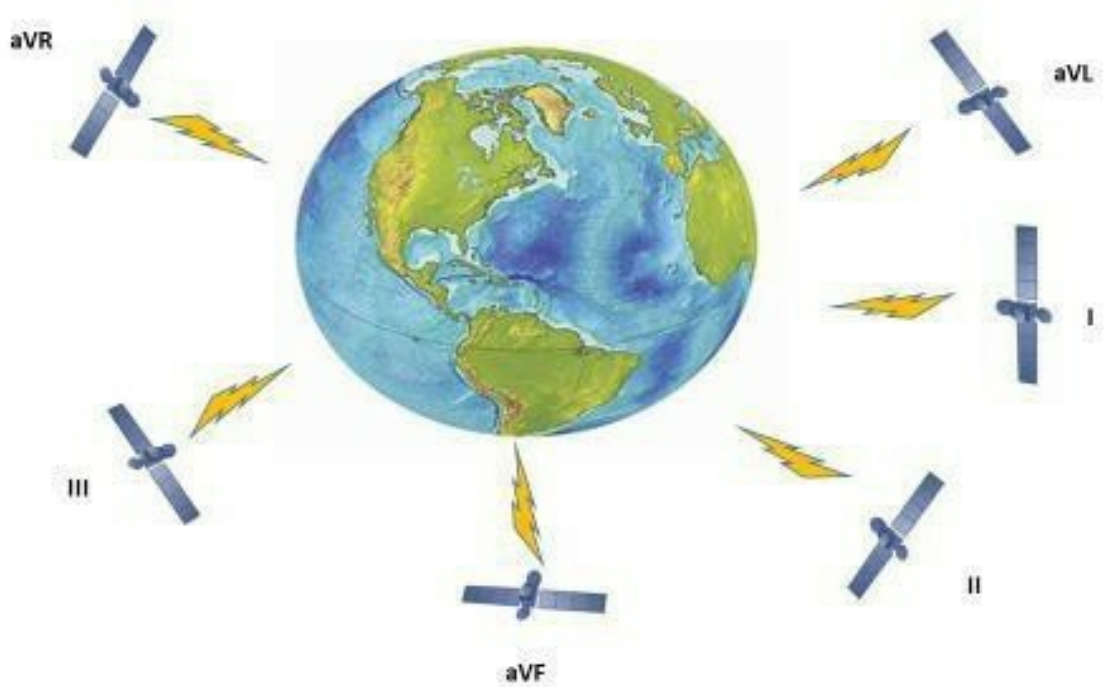
Electrocardiography helps in the detection of any cardiac abnormalities.
Usually, a 12-lead ECG is used in electrocardiography. The clinician will place ten electrodes on the limbs of the patient and also on the surface of the chest. By so doing, it becomes possible to capture the direction and the magnitude of the heart's electrical depolarization at every moment throughout the cardiac cycle. This medical procedure results in the production of a graph – with the voltage on the Y-axis and the time on the X-axis.

What Are Leads Used For?

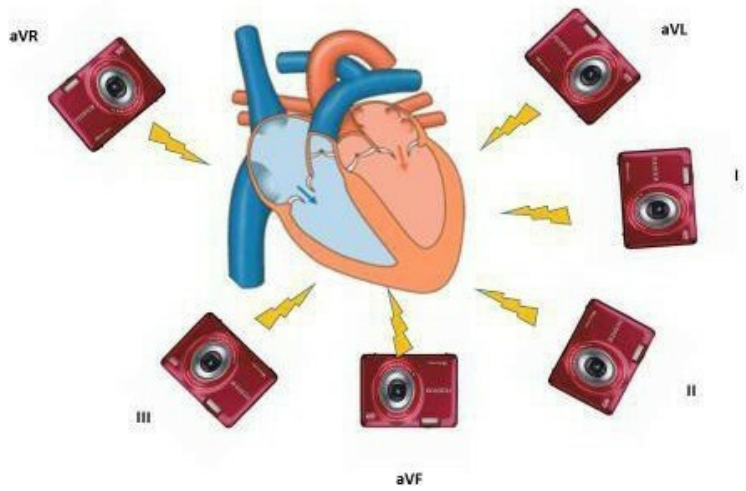
To record the heart's electrical activity, electrolytes are placed on the body to measure the information that we receive on EKG. The standard 12-lead EKG comprises of two lead types: chest leads and limb leads. Each of these leads has a unique angle (called the angle of orientation) from which it records the heart's activity. Because of this, it is crucial to be precise when preparing a patient for a 12-lead EKG.



A simple analogy using satellites and cameras may explain how leads function and what they tell us. The following illustration demonstrates this concept.

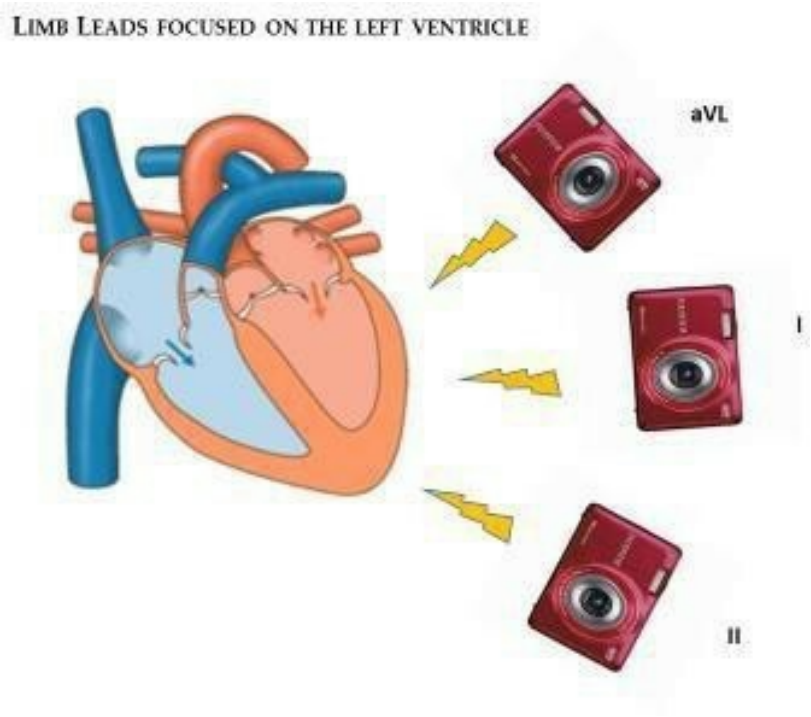


In this picture, six satellites circle the earth, each labeled with ECG designations. Looking at the picture, what part of the earth is satellite aVL viewing?
What about satellite II?
What about the remaining satellites?
Satellite aVL focuses on Africa, and satellite II focuses on the Atlantic Ocean. aVF views South America, while aVR focuses on the Pacific Ocean.
Let us replace the earth with a heart and satellites with cameras. Just as satellites circle the earth and record activity in specific geographic regions, limb leads encircle the heart and are poised to record the electrical activity in the anatomic areas on which they focus, thereby producing the typical ECG.

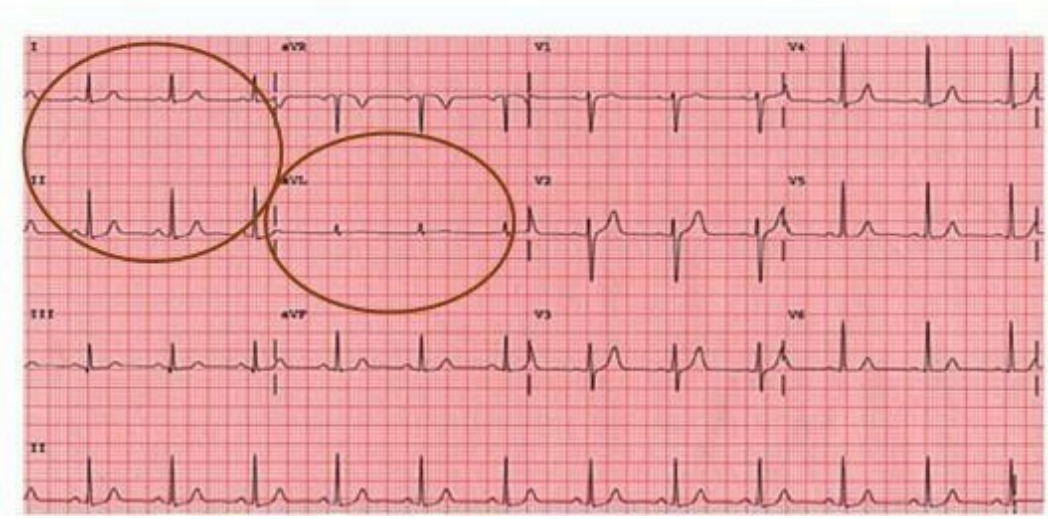


Examine the above cameras (leads). Two "cameras" focus exclusively on the left ventricle: leads aVL and I. Two leads focus exclusively on the right ventricle: leads aVF and III. Lead II focuses

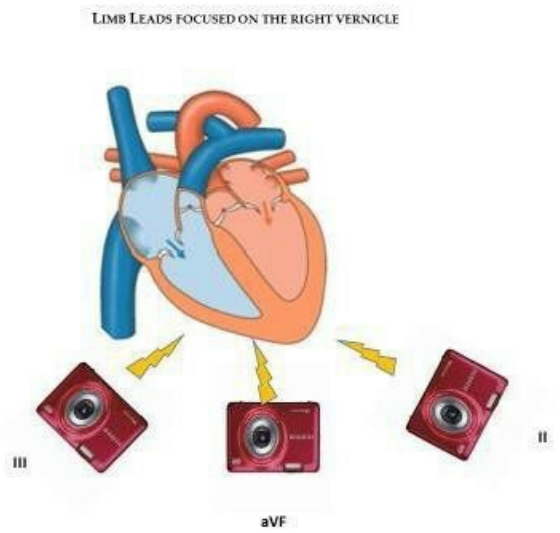
on the apex of the heart that includes a portion of BOTH ventricles.
Notice on the 12 lead ECG, the QRS complex in aVR is inverted because the direction of current is down and to the patient's left. The wave of depolarization is moving away from aVR, a positive terminal, toward the negative end of the aVR axis.
These limb leads to capture the electrical patterns occurring in the ventricles. In doing so, they can identify abnormal electrical patterns on the ECG, such as those produced by ischemia or infarction.
In the frontal plane, limb leads focus on what is occurring in both ventricles. Why ventricles? Because these are the muscular "pumps" that maintain cardiac output. Leads identify electrical abnormalities such as arrhythmia, ischemia, or infarction that may affect cardiac function. For example, if there is a myocardial infarction affecting the left ventricle, the infarction pattern will appear in those limb leads focused on the left ventricle, namely: Leads I, II, and aVL.

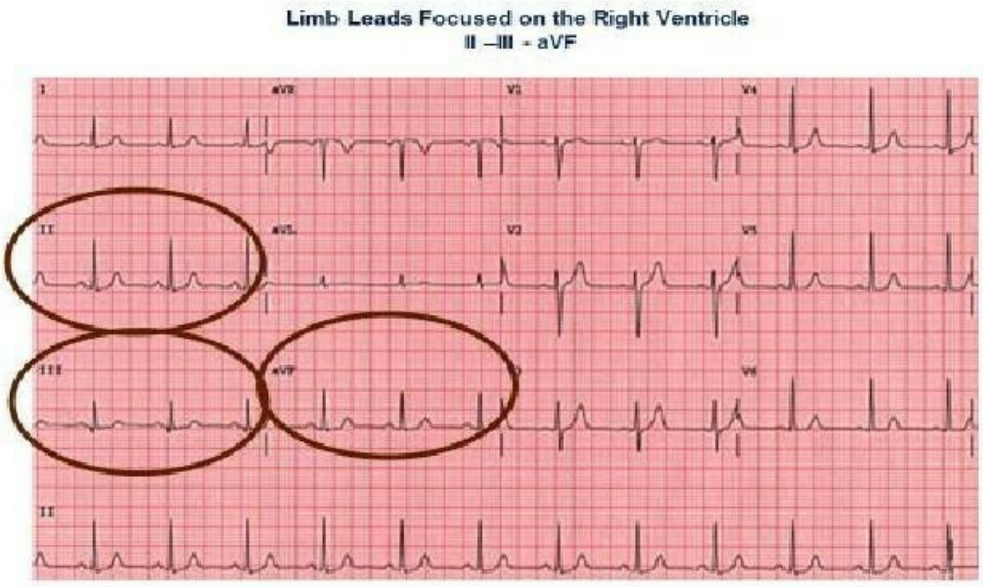


Limb Leads Focused on Left Ventricle I – II - aVL



Likewise, if there is a myocardial infarction affecting the right ventricle, the infarction pattern will appear in limb leads II, III, and aVF.

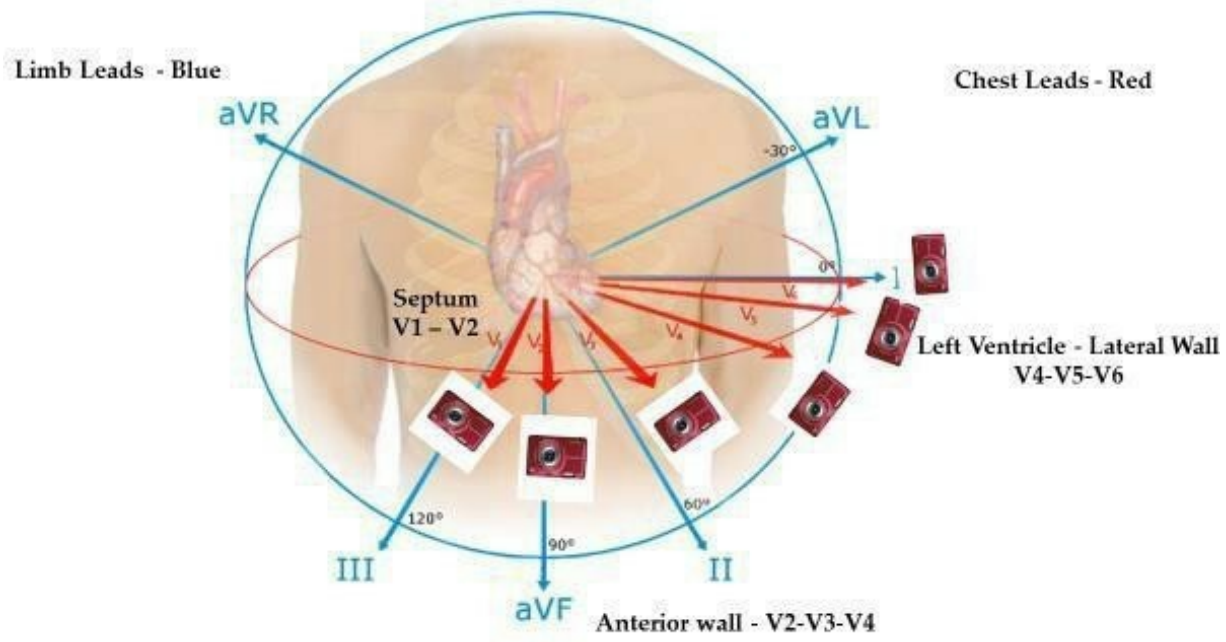




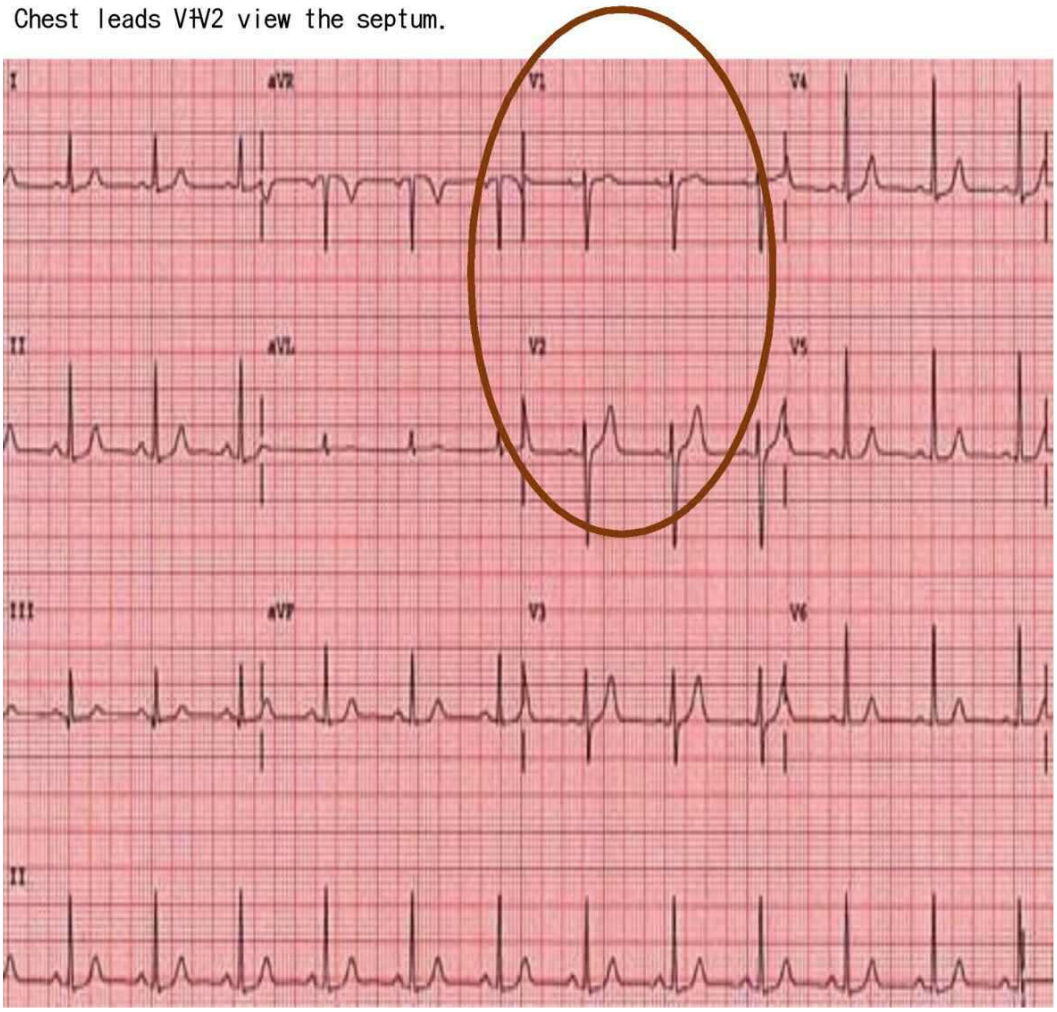
What about limb lead aVR? Some authors have referred to aVR as the "forgotten lead" because it does not focus on either ventricle. However, research suggests that elevated ST segments in this lead signify increased mortality in the setting of acute myocardial infarction.

Understanding Chest Leads

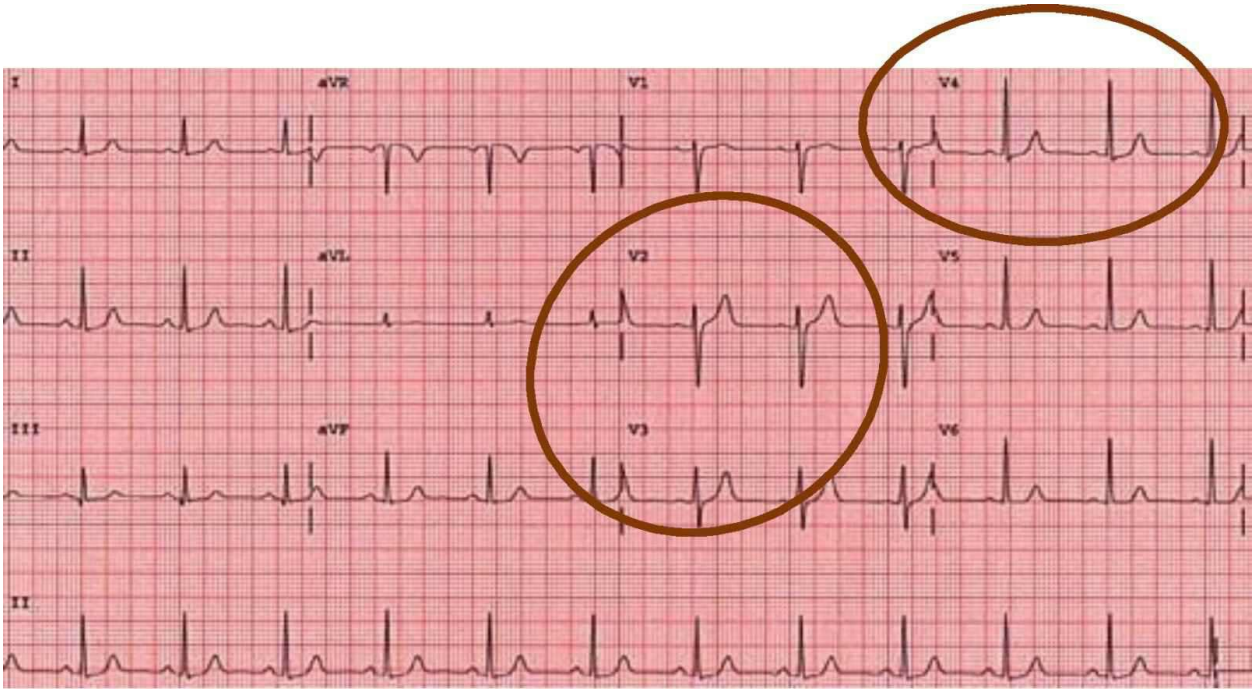
Chest leads also referred to as precordial leads, function in the very same manner as limb leads. However, rather than seeing the heart in a frontal plane, these leads view the heart in the cross-sectional plane, i.e., from front to back, as red arrows demonstrate in the following picture.



2015-03-17 05 Npatchett, MD
Chest lead "cameras" focus on three specific areas of the heart, namely, the septum (V1-V2), the anterior wall of the left ventricle (V2-V3-V4), and the lateral wall of the left ventricle (V4-V5-V6).

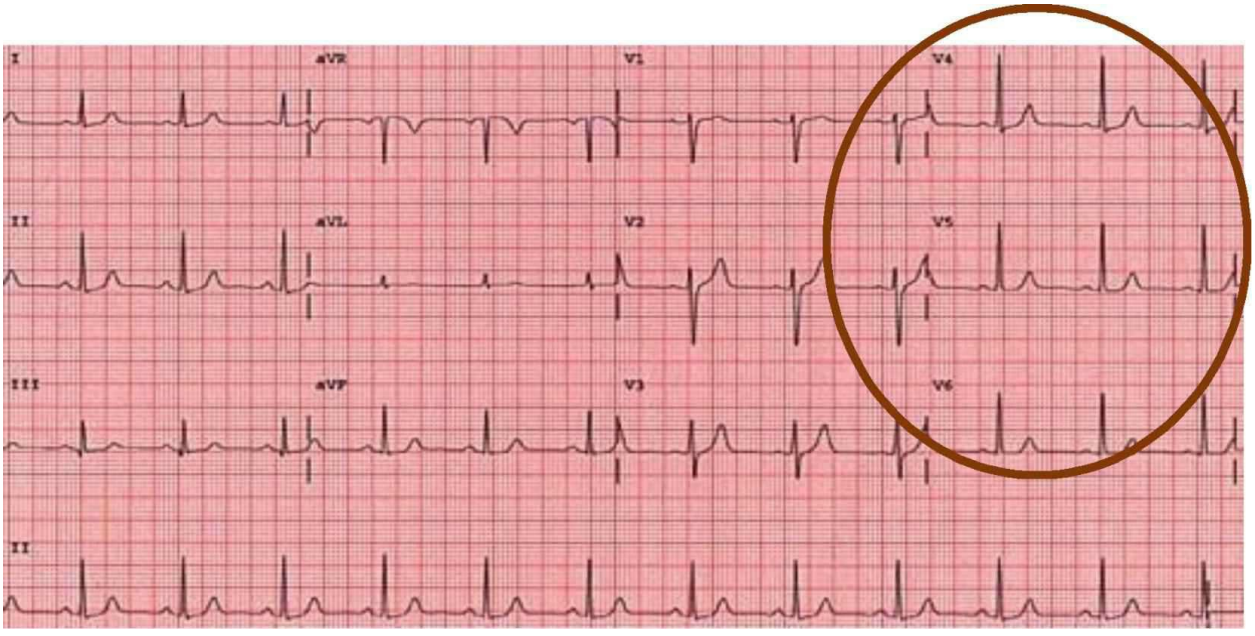


While the most common cause of complete heart block associated with myocardial infarction is occlusion of the right coronary artery, the involvement of the septum in left anterior descending coronary artery infarction is particularly ominous as this affects the bundle of His. Injury to the bundle of His may result in abrupt heart block without warning. For this reason, some advocate placement of an external cardiac pacemaker on standby in managing anterior wall myocardial infarction. Chest leads V2-V3-V4 monitor the "anterior wall" of the heart that houses the septal Bundle of His.



V2-V3-V4 – Anterior Wall with Bundle of His

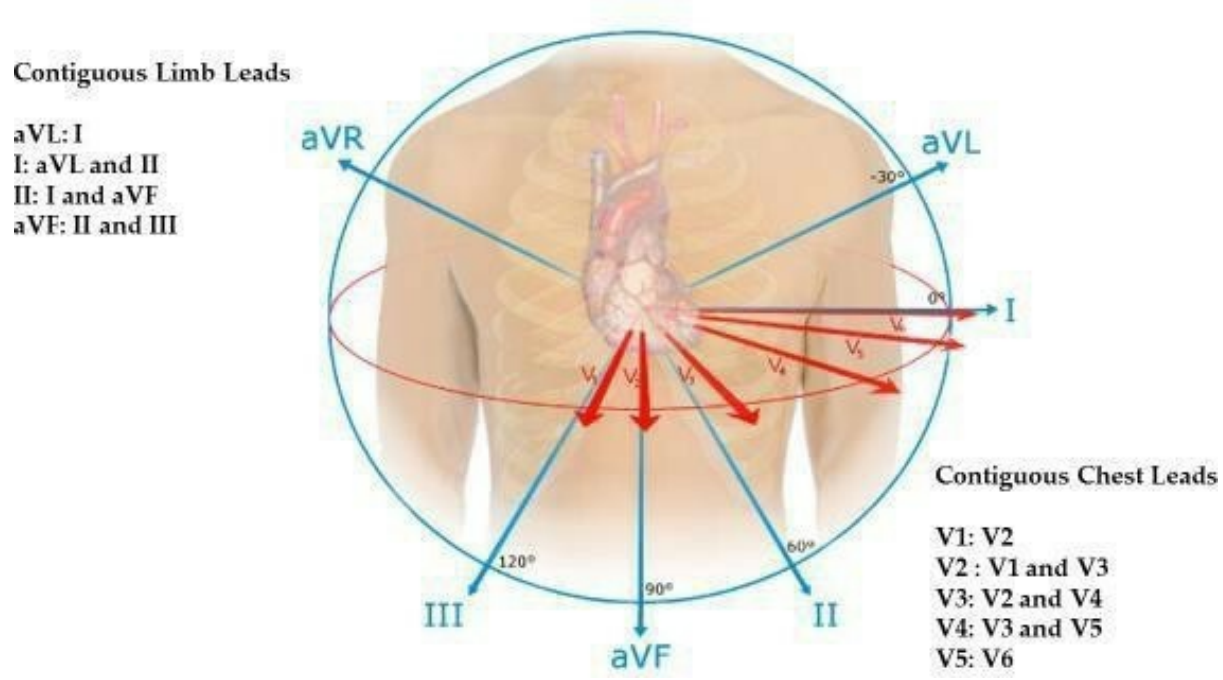
Chest leads V4-V5-V6 focus on the **lateral wall** of the left ventricle just as do limb leads I- II- aVL. Injury to the left ventricle will demonstrate ischemia and infarction patterns in these leads.
Chest leads focused on the lateral wall of the left ventricle V4-V5-V6



Realize that leads do not possess the same degree of anatomic precision as angiograms. There may be some degree of overlap, particularly with chest leads. While chest lead V2 focuses on the septum, it also sees a portion of the anterior wall of the left ventricle. Likewise, V4 views both the anterior as well as lateral wall of the left ventricle. V2 and V4 are transitional leads, focusing on both the anterior wall as well as the lateral wall of the left ventricle.

Contiguous Leads in Ischemia and Infarction

Contiguous leads are simply adjacent or adjoining leads. ECG confirmation of either ischemia or infarction must demonstrate characteristic abnormalities in at least two or more contiguous leads. The following diagrams illustrate adjacent, i.e., contiguous, limb and chest lead.



ECG infarction and ischemic patterns should appear in at least two or more adjacent limb and/or chest leads. Appearance in a single lead is suspicious but not diagnostic. Frequently cardiologists refer to such findings as "non-specific changes."

Types of EKG

1. Resting EKG
2. The stress of Exercise EKG
3. Ambulatory EKG

Chapter 7. Execution

ECG Tools

There are certain instruments that help with ECG interpretation:

Calipers

Calipers are perhaps the most important tool in ECG interpretation. Place one pointed edge against one end of what you measure and the other edge at the other end to use one. This position will be maintained by the calipers. You can then move on to a blank area of the ECG strip. Count the number of boxes to get your measurements (example: 1 small box = 0.04 seconds, 1 big box = 0.20 seconds, and so on).
You can use calipers to check whether the distance between complexes is equal. Measure the complex with the two pins. Hold the right pin down and gently swing the left pin to the next complex. If they are the same, the next complex will coincide with the pin. This technique is called “walking,” and it is useful for determining complex regularity and detecting ECG abnormalities.
Aside from width, calipers can also measure wave heights. You can likewise “walk” the caliper so that you will know the biggest or smallest complexes and see whether a wave is more positive or more negative.

ECG Ruler

This helps with measuring ECG, but it is not that necessary since a caliper can do what this does.

Axis-wheel Rulers

Axis-wheel rulers are used to calculating waves and segments’ true axis. This ruler has a red line and a perpendicular arrow.

Straight edge

It evaluates the baseline and can determine elevations and depressions.
At first, you may be dependent on these instruments, which can enable you to make accurate diagnoses. After a lot of practice, you will be able to make measurements without having to use them quickly.

Calibration

The end of an ECG strip will usually have a calibration box, which is 10 mm high and 0.20 seconds wide. This says that the ECG follows the standard format. This has a rate of 25 mm/sec.
There are ECGs that have a half-standard calibration, especially when the complexes are so large that they overlap. When this is the case, the calibration box will have a stair-like design.
The third calibration is set at 50 mm/sec. The calibration box is 0.40 seconds in width.

It is essential to check the calibration of the ECG in order to evaluate the tracings correctly.
These are some of the basic things you need to know before diving into the details of ECG interpretation.

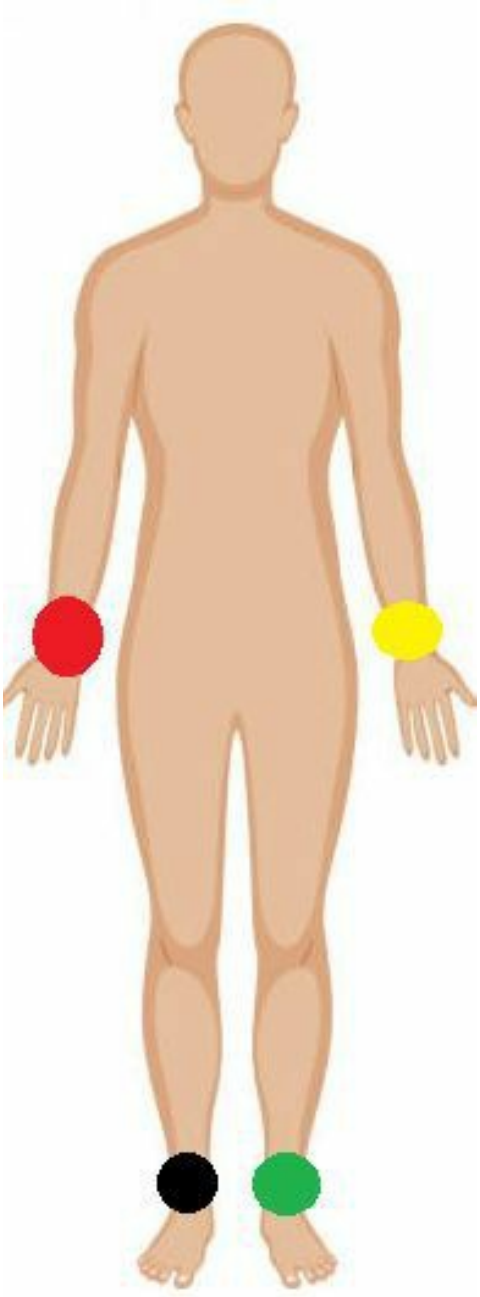
The positioning of the Patient

The essential details are given below.

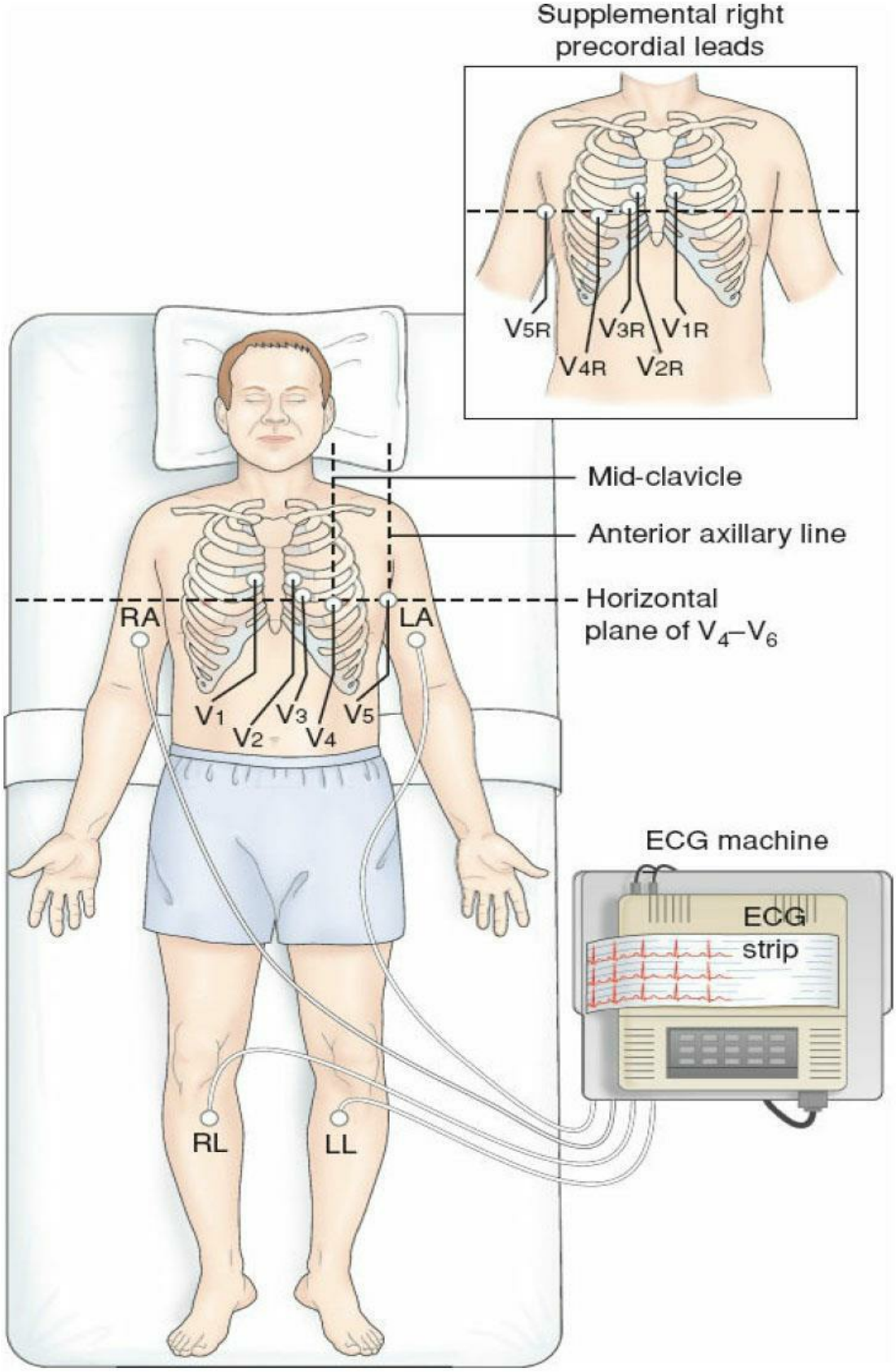
- Ensure that electronic devices (e.g., smartphones) are removed from the patient. These devices can produce artifacts (interference) and cause problems with the readings.
- Try to put the patient in supine or Semi-Fowler's position. If the patient cannot tolerate both supine and Semi-Fowler's position, you can perform the ECG on the patient in a more elevated position.
- Ask the patient to relax his shoulders and keep his legs uncrossed with his arms lying flat on his side.

The positioning of the Electrodes

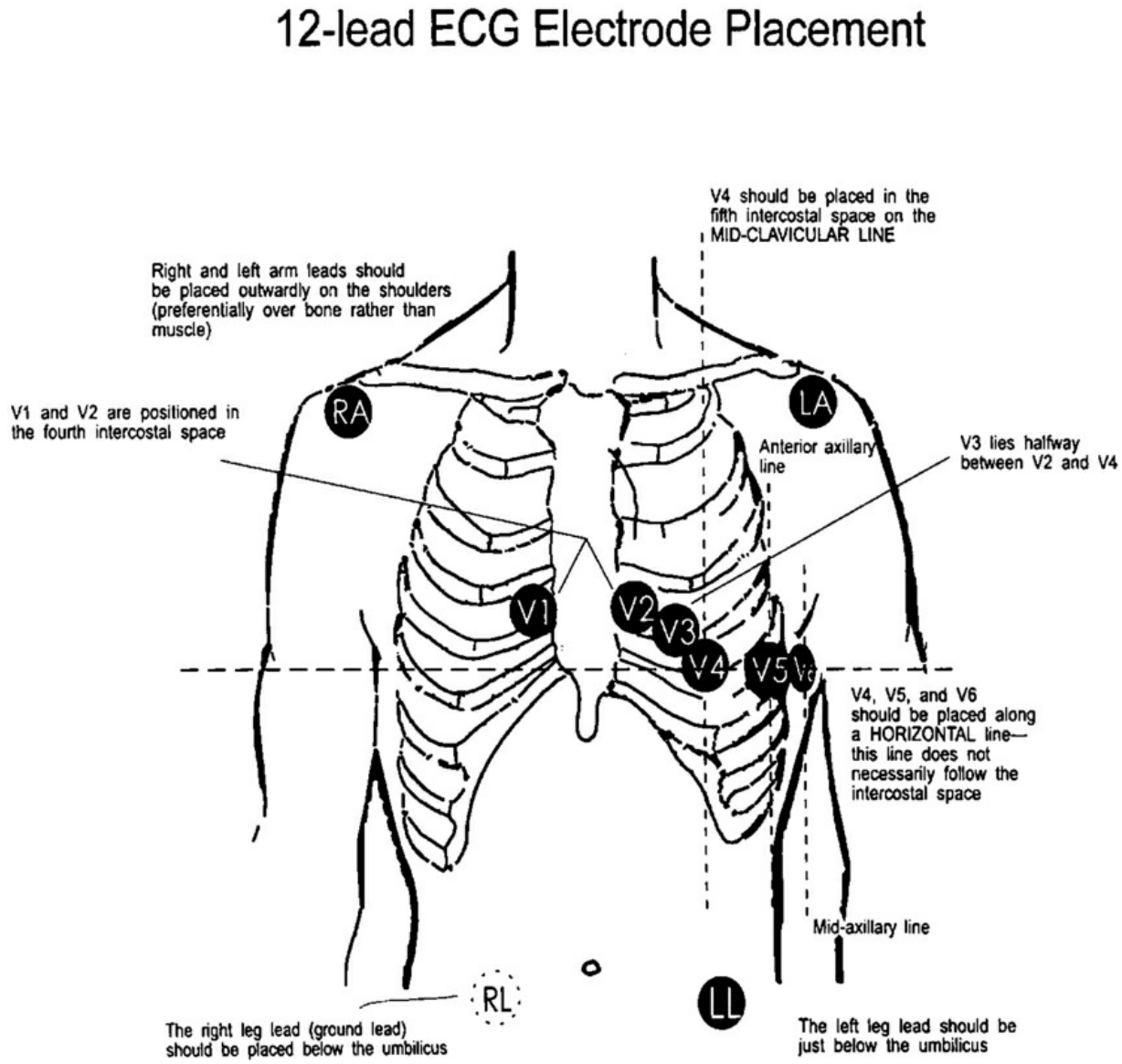
It involves the proper placement of limb and chest electrodes at their ideal positions. Interchanging the limb electrodes or mild displacement of chest electrodes causes lead reversal patterns and artifacts in ECG.
The limb electrodes are placed according to their color code, as shown below.



ELECTRODES	COLOUR CODE
RIGHT ARM	RED
LEFT ARM	YELLOW
RIGHT LEG	BLACK
LEFT LEG	GREEN


Supplemental right precordial leads
V5R
V4R
V3R
V2R
V1R
Mid-clavicle
Anterior axillary line
Horizontal plane of V4–V6
RA
LA
V1
V2
V3
V4
V5
RL
LL
ECG machine
ECG strip

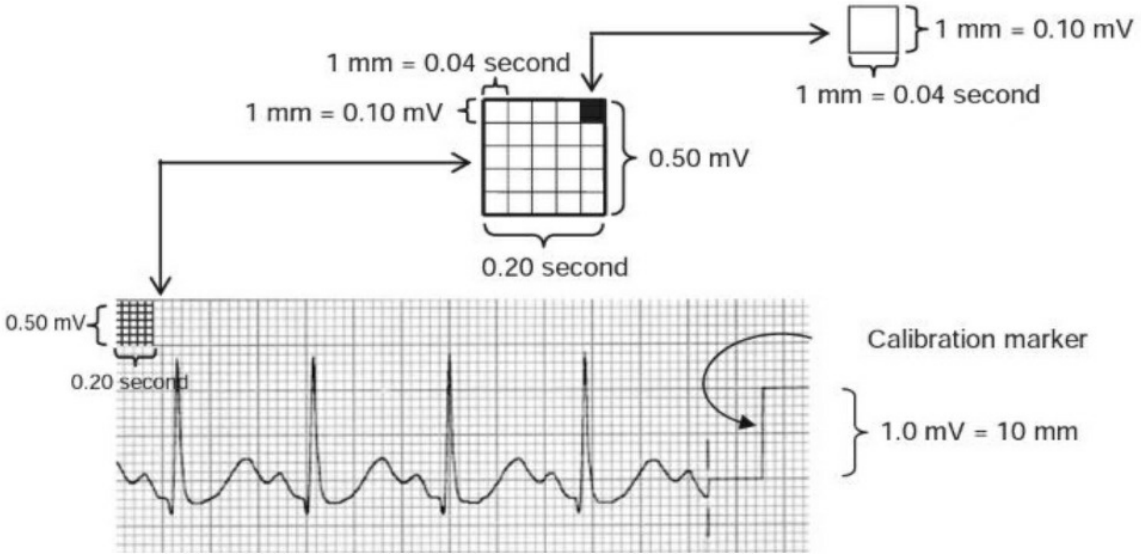
The positioning of Chest Electrodes



Chest leads are also called Exploring electrodes or precordial leads.

ECG Trace

ECG Paper



The small squares have a side of 1 mm. So, the width (x- axis) is 1mm, and height (y- axis) is 1mm. The large squares have a side of 5 mm. So, the width (x- axis) is 5mm, and height (y- axis) is 5 mm.

THE WIDTH of THESE SQUARES REPRESENT TIME, and the HEIGHT REPRESENTS AMPLITUDE.

WIDTH

The width of a small square is 1 mm = 40 ms (0.04 seconds)

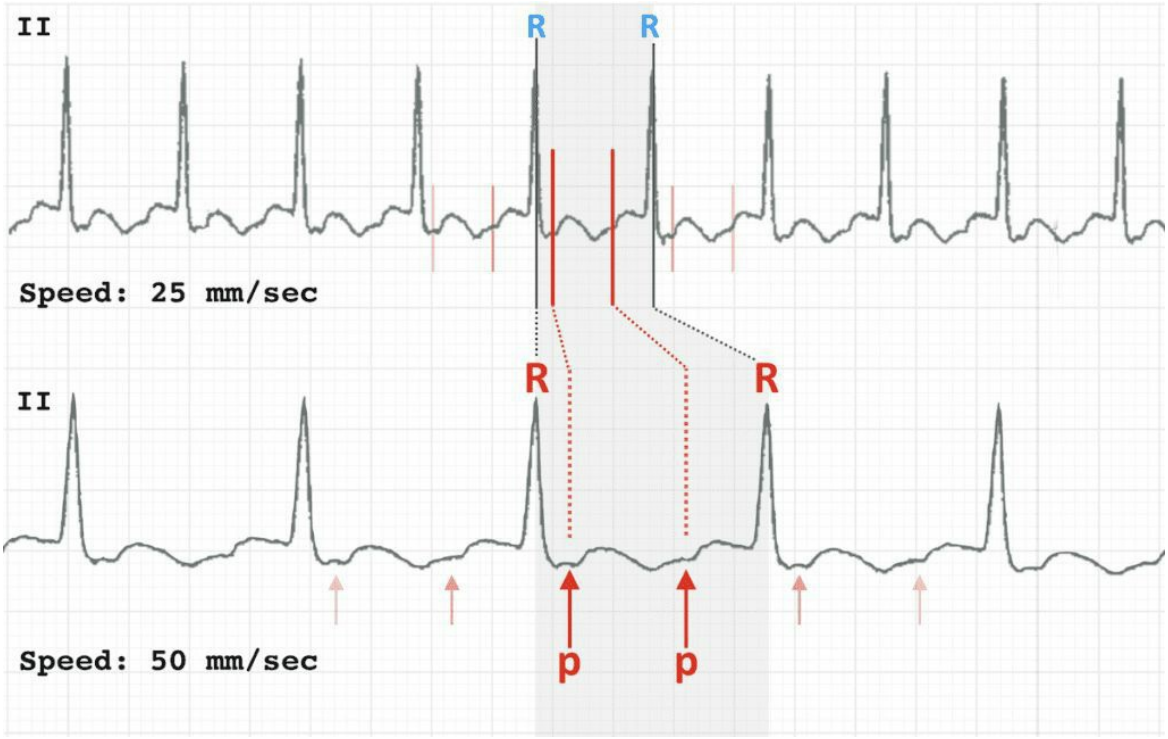
The width of a large square is 5 mm = 200 ms (0.2 seconds)

HEIGHT

The height of a small square is 1 mm = 0.1 mv

The height of a large square is 5 mm = 0.5mv

Speed



The usual speed Of the ECG paper is 25 mm/second. It can be altered in an ECG machine manually. In cases of severe Tachycardia, the speed of ECG paper is increased to 50 mm/second. As the paper moves faster, the distance between two complexes increases, helping in better recognition of ECG patterns and waves.

WIDTH

One small square	40 ms
One large square	200 ms

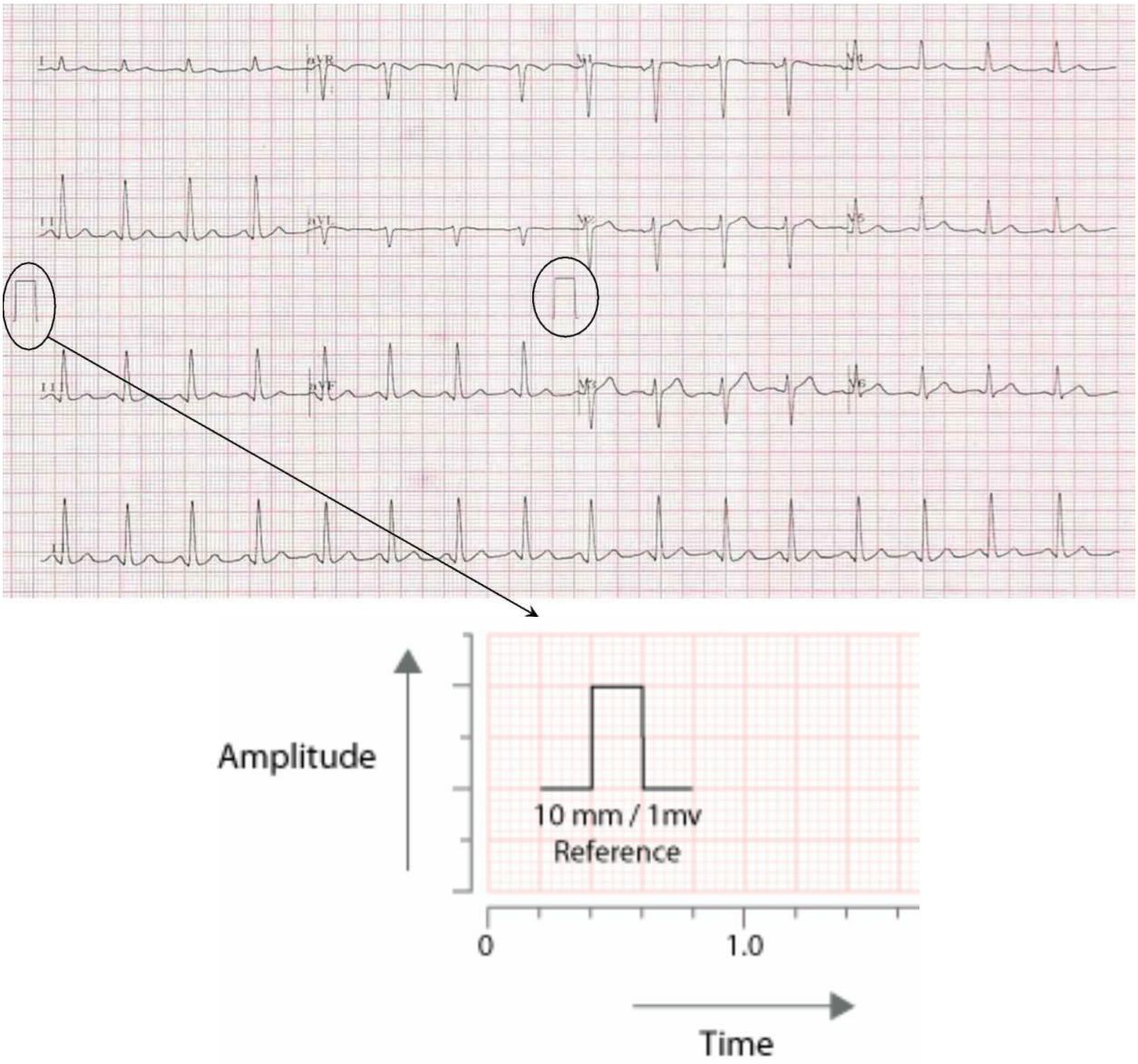
HEIGHT

1 small square	0.1 mV
One large square	0.5 mV

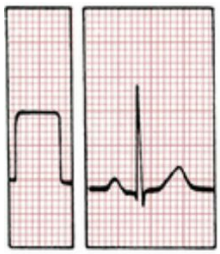
Often, we use the term box instead of squares, and both are used interchangeably.
Where are we supposed to look first when we are given an ECG?
The first and the foremost thing to look at in the ECG is its **Standardization**, which is indicated by the Symbol. In a standardized ECG, the height and width of the complexes are precise. However, in an unstandardized ECG, they may vary in size and shape.

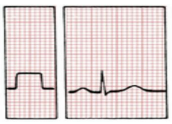
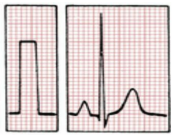
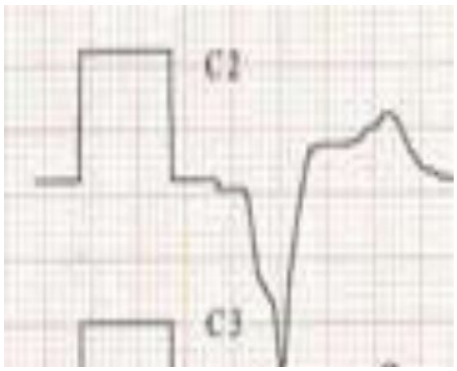
Standardization

In simpler terms, standardization is considered a quality indicator for ECGs.



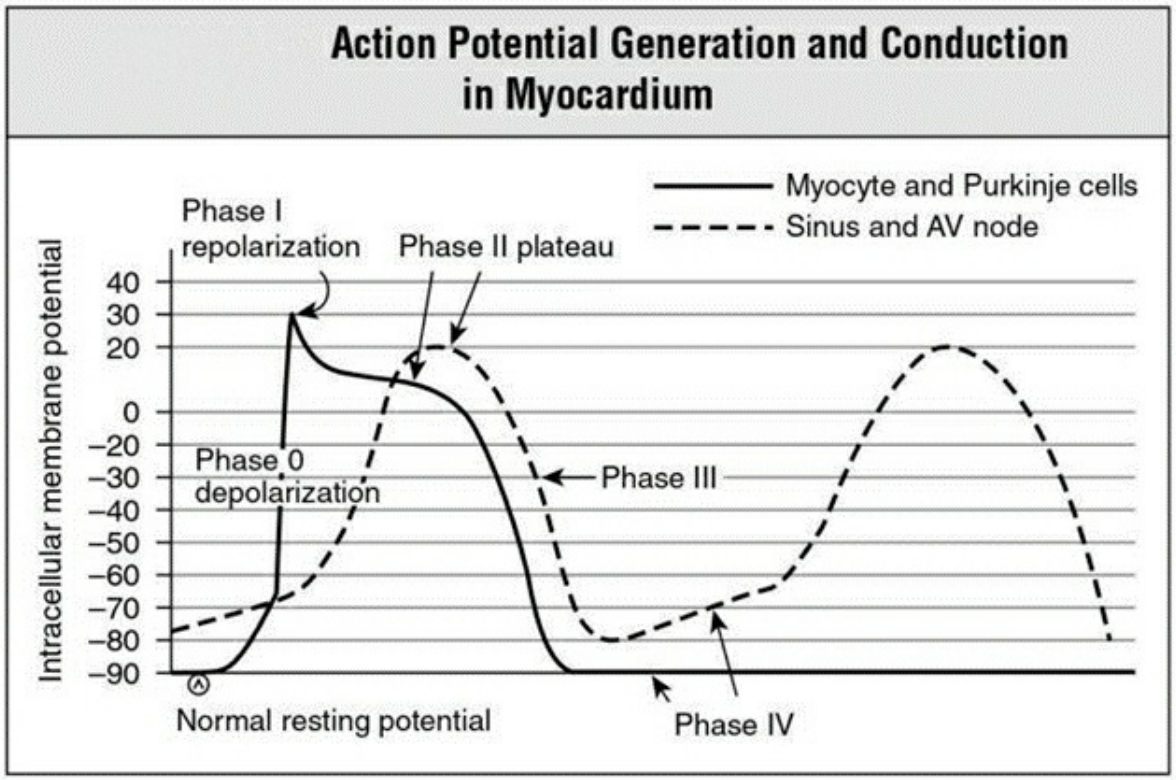
The amplitude of standardization is 10 mm = 10 small squares = 1mv along the Y-axis. The width of the standardization is 5 mm = 5 small squares = 200 ms along X-axis.
If the ECG is not standardized correctly on the first instance, it should be appropriately repeated standardized to avoid erroneous reporting.

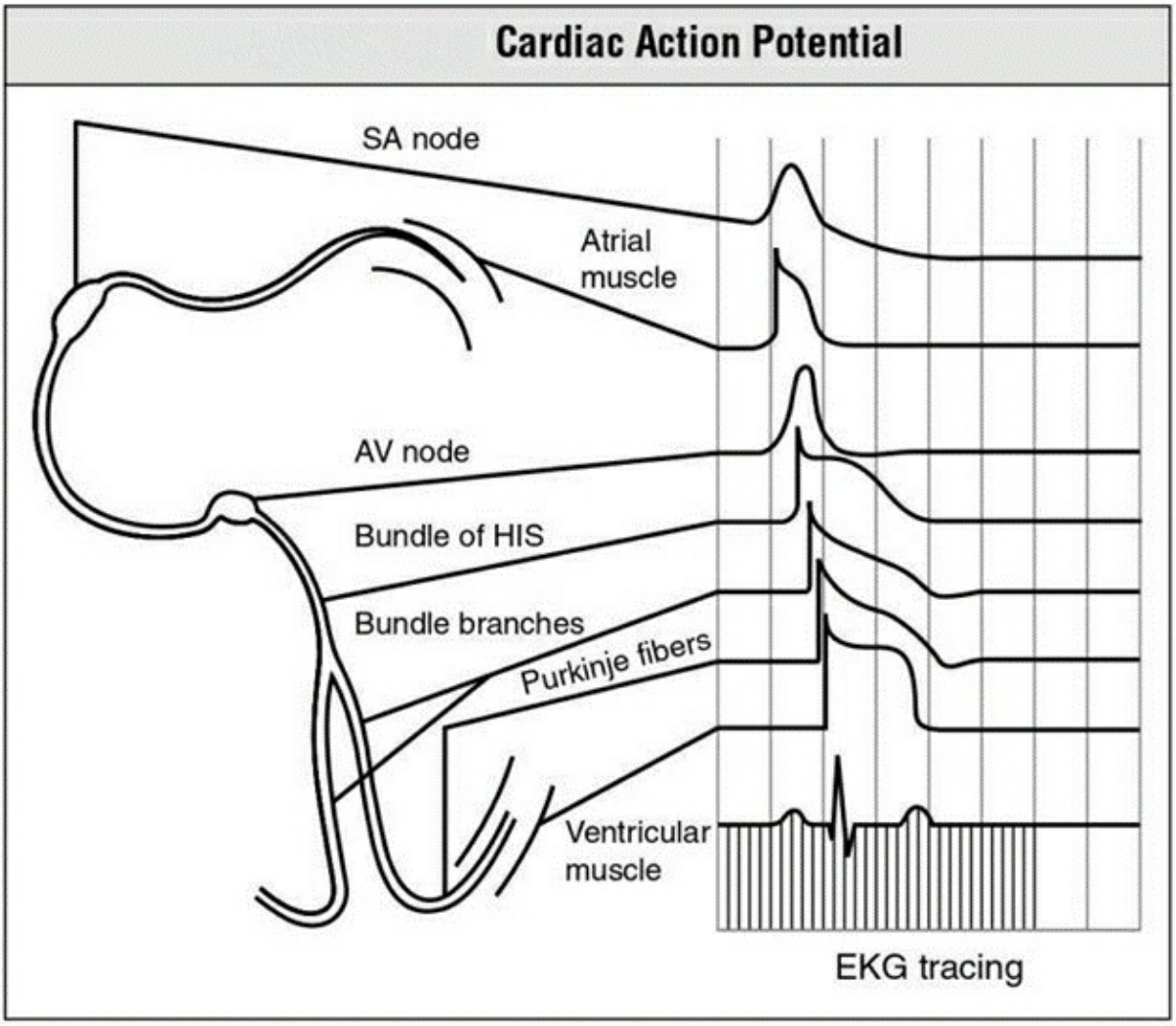
	Normal Standardized ECG Amplitude & Duration of the complex normal

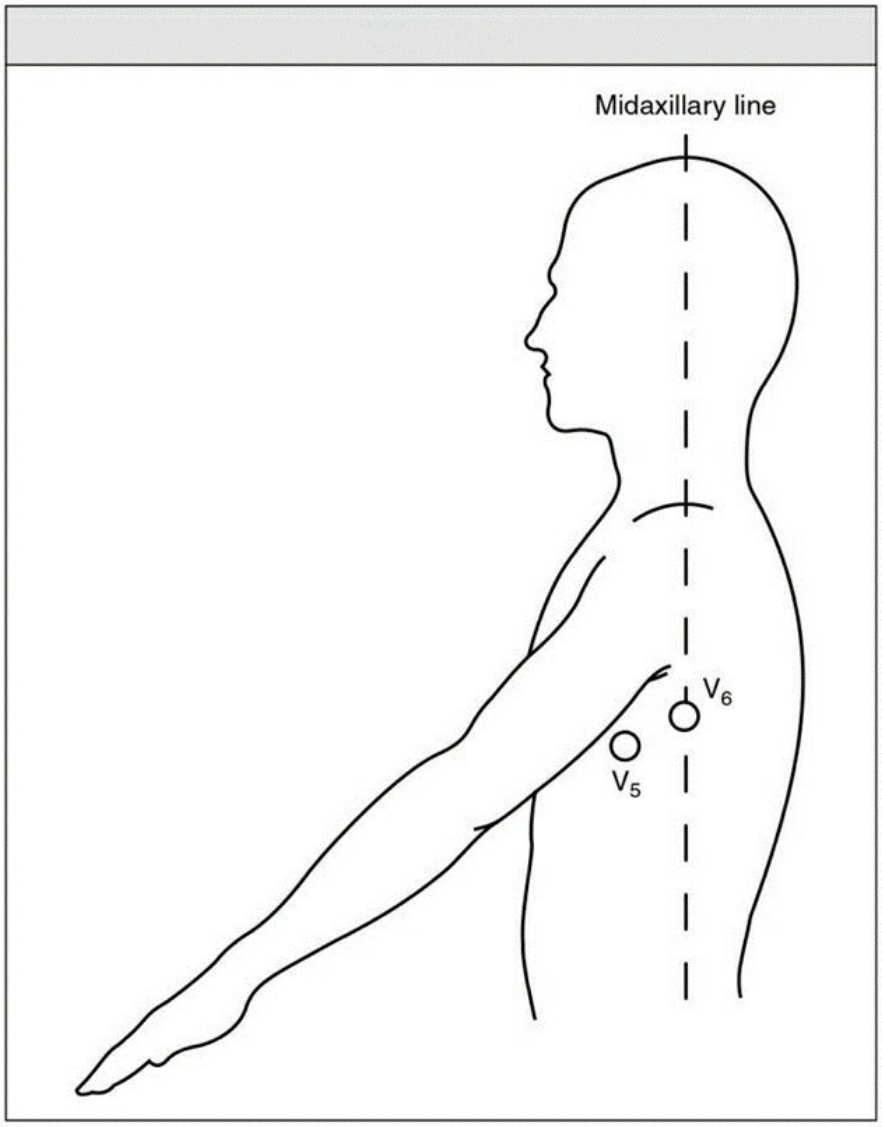
	Under Standardized ECG Amplitude decreased
	Over Standardized ECG Amplitude increased
	Over Standardized ECG Duration increased

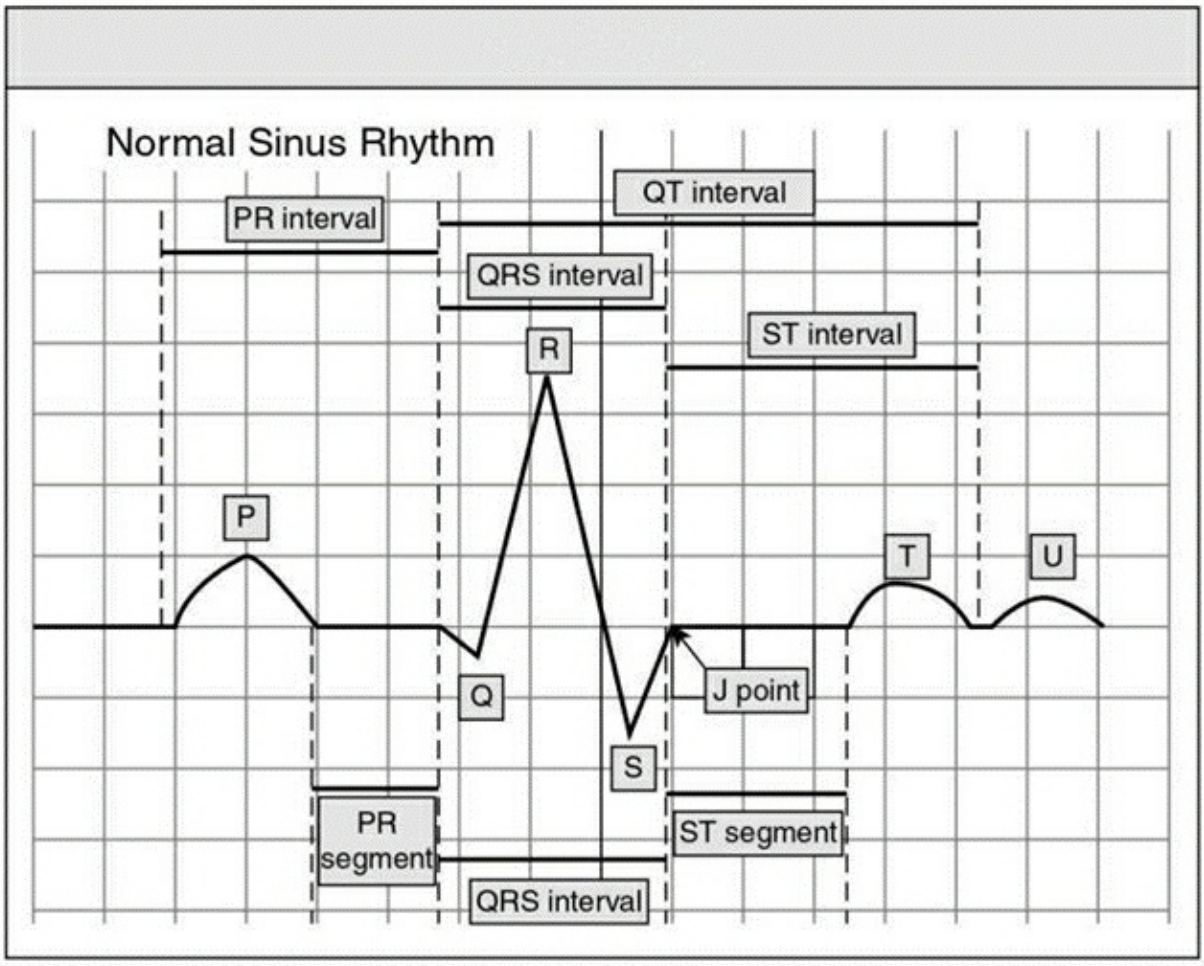
NOTE

As we use thermal paper for recording ECGs, the tracings may fade off after a few months. So, it is advisable to have a soft copy or photocopy for future reference and medicolegal aspects.



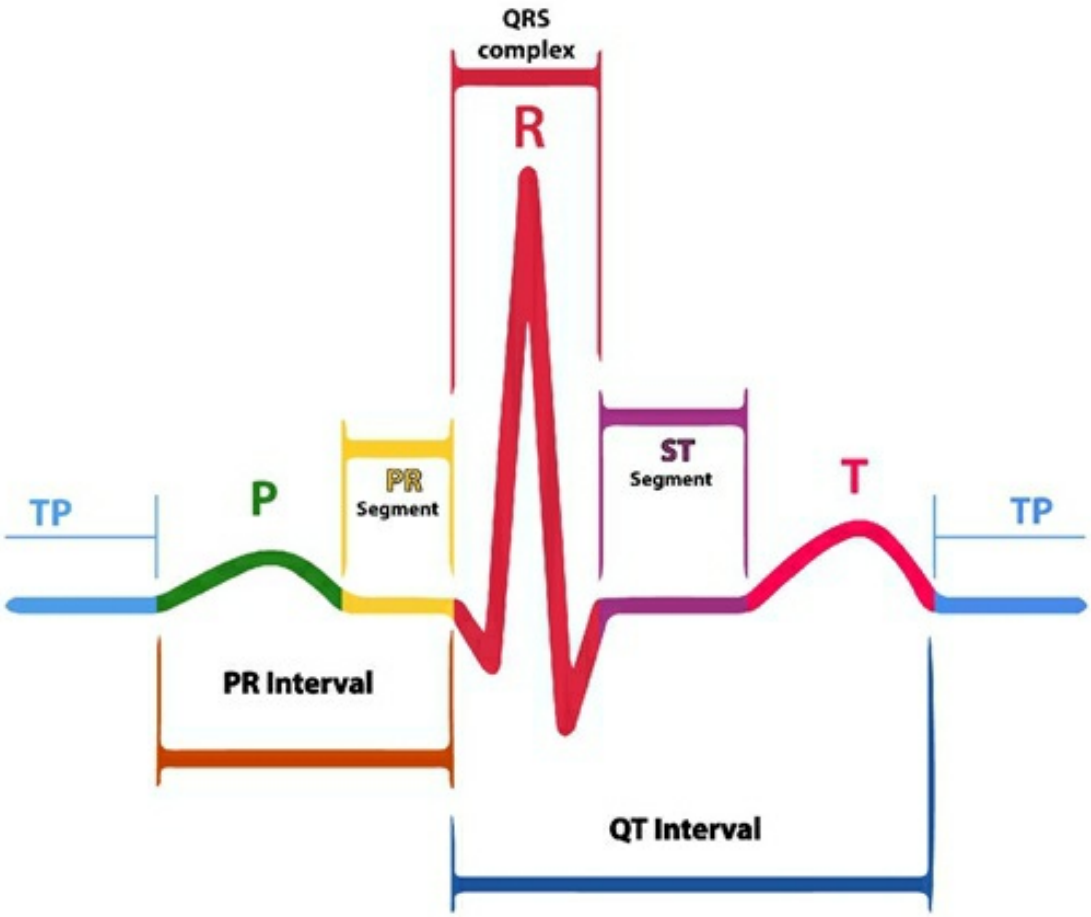

Cardiac Action Potential
SA node
Atrial muscle
AV node
Bundle of HIS
Bundle branches
Purkinje fibers
Ventricular muscle
EKG tracing


Midaxillary line
V6
V5


Normal Sinus Rhythm
PR interval
QT interval
QRS interval
ST interval
R
P
T
U
Q
J point
S
PR segment
ST segment
QRS interval

EKG: Waves and Intervals		
▪ **P wave** = depolarization of the atria		
▪ **QRS** = depolarization of the ventricle		
▪ **T wave** = repolarization of the ventricle		
Normal Values		
	Duration (horizontal axis)	**Height (vertical axis)**
P wave	<0.12 s	<2.5 mm
P-R interval	0.12-0.20 s	
QRS interval	0.08-0.10 s	
QT interval	0.35-0.44 s	
QTc interval = QT interval divided by the square root of R-R interval		
Age group	**QTc interval by age**	
0-2 yrs	0.37-0.53	
2-10 yrs	0.39-0.42	
10-14 yrs	0.40-0.42	
>15 yrs	0.35-0.44	

Chapter 8. The ECG Complex



Components of the ECG complex

The ECG records waves, intervals, and segments. These have particular morphologies (forms), axes, durations, and amplitudes when typical. When the ECG readings are different from these traits, there may be something wrong with the heart.

A wave is a deflection from a baseline, which is the line from one TP segment to another one next to it. It can be single, positive, negative, biphasic, isolated, or have multiple parts that can be positive or negative.

An interval is the time distance between two cardiac events. A segment is a specific part of a complex on an ECG. A segment is different from an interval.

This is the normal sequence of the waves:

Tall waves are given big letters, while small waves are labeled with small letters.

Prime waves

Waves are called prime when they cross the baseline or change directions.

When there are extra waves where they aren't supposed to be, they are labeled as prime waves.

A wave can be a double prime when it occurs twice.

The P Wave

The P wave is usually the first wave on the TP segment. It represents the atria's electrical depolarization. The wave begins when the SA node fires, and it embodies the impulse transmission through the internodal pathways, the Bachmann bundle, and the atrial myocytes.
Since the P wave represents atrial depolarization, P wave abnormalities signify atrial abnormalities. Check the inferior leads (II, III, and aVF) and precordial lead V1 for this.
The wave duration is between 0.08 – 0.11 seconds or less than 120 ms. Its axis is commonly directed downwards and to the left (Axis: 0 to 75 degrees) since it goes through the atrioventricular node and atrial appendages.
The first one-third of the wave embodies the right atrial activation, the last third represents the left atrial activation, and the middle is the blend between the two.
P waves are normally upright in leads I and II and inverted in lead aVR. They are monophasic in lead II and biphasic in V1.
In V1, the P wave is biphasic and begins with a positive deflection, showing right atrial activation, and ends with a negative deflection, which reflects left atrial activation. Because of this, the state of each individual atrium can be determined by looking at each part of this waveform.
These are some things that can be known from P waves:

The TP Wave

The TP wave symbolizes the repolarization of the atria. This moves in the opposite direction of the P wave.
This is not commonly obvious because it coincides with the more prominent QRS wave.
The TP wave appears when the QRS is absent, such as in the case of AV dissociation or non-conducted beats. This also shows up in PR depression or in the ST-segment depression during sinus tachycardia.
It shows as ST depression because the QRS arrives earlier, and the TP wave draws the ST segment down.

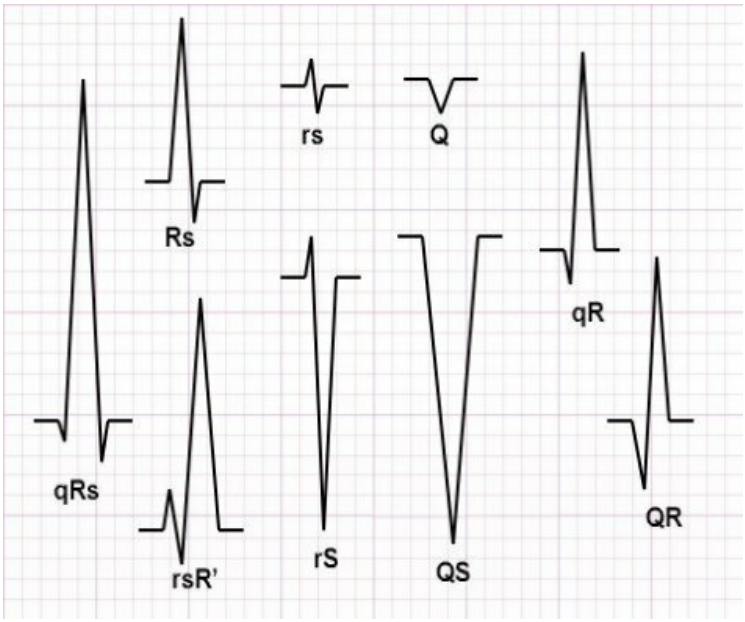
The PR Segment

The PR segment is normally lying along the baseline but can be depressed or elevated by up to 0.8 mm. PR segment abnormalities indicate atrial infarctions/ischemia and pericarditis.
The PR segment shows the transmission of the electrical depolarization impulse through the AV node, the bundle of His, bundle branches, and the Purkinje system.

The PR Interval

The PR interval involves events from the start of the electrical impulse in the SA node to ventricular depolarization. (Beginning of impulse, atrial depolarization, and repolarization, stimulation of AV node, His bundle, bundle branch, and Purkinje System).
This normally lasts from 0.12 – 0.20 seconds.
If it's longer than 0.20 seconds, it is a sign of a first-degree AV block.
It can also be called the PQ interval when a Q wave begins the QRS complex.

The QRS Complex



The QRS complex reflects ventricular depolarization. It usually lasts 0.06 – 0.11 seconds with an axis of -30 to +105 degrees, going downward and to the left.

Q Wave

A Q wave is considered significant if it lasts for 0.03 seconds or longer or if it is as tall or taller than 1/3 of the R wave. When these conditions are present, there is a myocardial infarction (MI). Insignificant Q waves are traditionally found in me, aVl, and V6, and these are caused by septal innervations. These are usually called septal Qs.

Intrinsicoid Deflection

This begins from the start of the QRS complex to the start of the downward slope of the R wave, in leads that begin with an R wave and do not have a Q wave. It symbolizes the time taken for the electrical impulse to traverse the Purkinje system from the inner layer to the outer layer of the heart.

It is shorter in the right precordial leads (V1-V2) because the right ventricle is thinner than the left.

The intrinsicoid deflection will be longer if the myocardium is thicker than normal (e.g., Ventricular hypertrophy) or when the electrical system conducts slower in that area because of a delay (e.g., Left bundle branch block).

These are the normal upper limits for intrinsicoid deflection:

Left precordials = 0.045 seconds

Right precordials = 0.035 seconds

The ST Segment

The ST segment is the electrically neutral period in between ventricular depolarization and repolarization. In this phase, the myocardium is maintaining its contraction to push the blood from the ventricles. Its axis is normally inferior and to the left.
This is the section from the QRS complex's end to the T wave's start. It is usually found on the baseline but can deviate up to 1 mm from it in normal patients' limb leads and 3 mm in the right precordial. This may be caused by left ventricular hypertrophy or an early repolarization pattern.
The J point marks the spot where the QRS complex stops and the ST segment begins.
When the ST segment is elevated, it should be considered as significant, as it can reveal a myocardial infarction or injury.

The T Wave

The T wave signifies ventricular repolarization. This is the next positive or negative deflection after the ST segment. It is expected to begin in the same direction as that of the QRS complex. The axis is downward and to the left for this wave as well.
The T wave is asymmetrical, with the first part dropping or rising slowly and the last part moving rapidly.
To check whether the T wave is symmetrical or not, draw a perpendicular line from the wave's peak to the baseline and compare the two sides.
Symmetric Ts usually signify problems.

The QT Interval

The QT interval comprises the QRS complex, ST segment, and T wave.
It involves cardiac events of ventricular systole, that is, from the start of ventricular depolarization until the end of the repolarization cycle.
The QT interval depends on the patient's age, sex, heart rate, and electrolyte condition.
A prolonged QT can mean arrhythmias.
To obtain QTc, add QT + 1.75 * (ventricular rate -60)
The QTc interval usually lasts 0.410 seconds, and anything longer than .419 is considered prolonged.

The U Wave

The U wave is the small wave commonly seen after the T wave and before the following P wave. This has low voltage and has the same direction as the T wave.
It is not clear as to what it symbolizes, but it is theorized that it stands for ventricular depolarization and endocardial repolarization.
It is seen in normal individuals, especially those with bradycardia (slow heartbeats). It is also evident in hypokalemia or low potassium in the blood, thus there is no hyperkalemia (high levels of potassium) when a U wave exists.

The R-R Interval

The R-R interval is the distance between two identical points or peaks of two consecutive QRS complexes.
This is used to determine whether the rhythm is regular or irregular. Those with traditional rhythms have consistent R-R intervals.

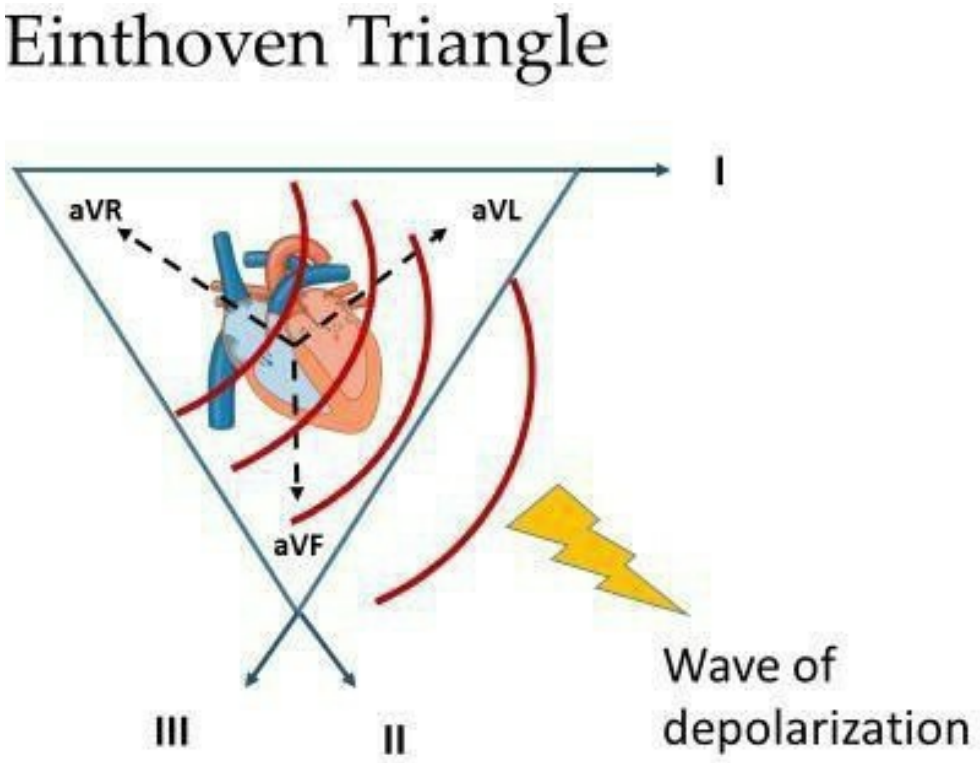
The P-P Interval

This is the distance between two identical points on a P wave and the next one. This is used to assess rhythm abnormalities such as atrial flutter, Wenckeback second-degree heart block, and third-degree heart block.

Baseline

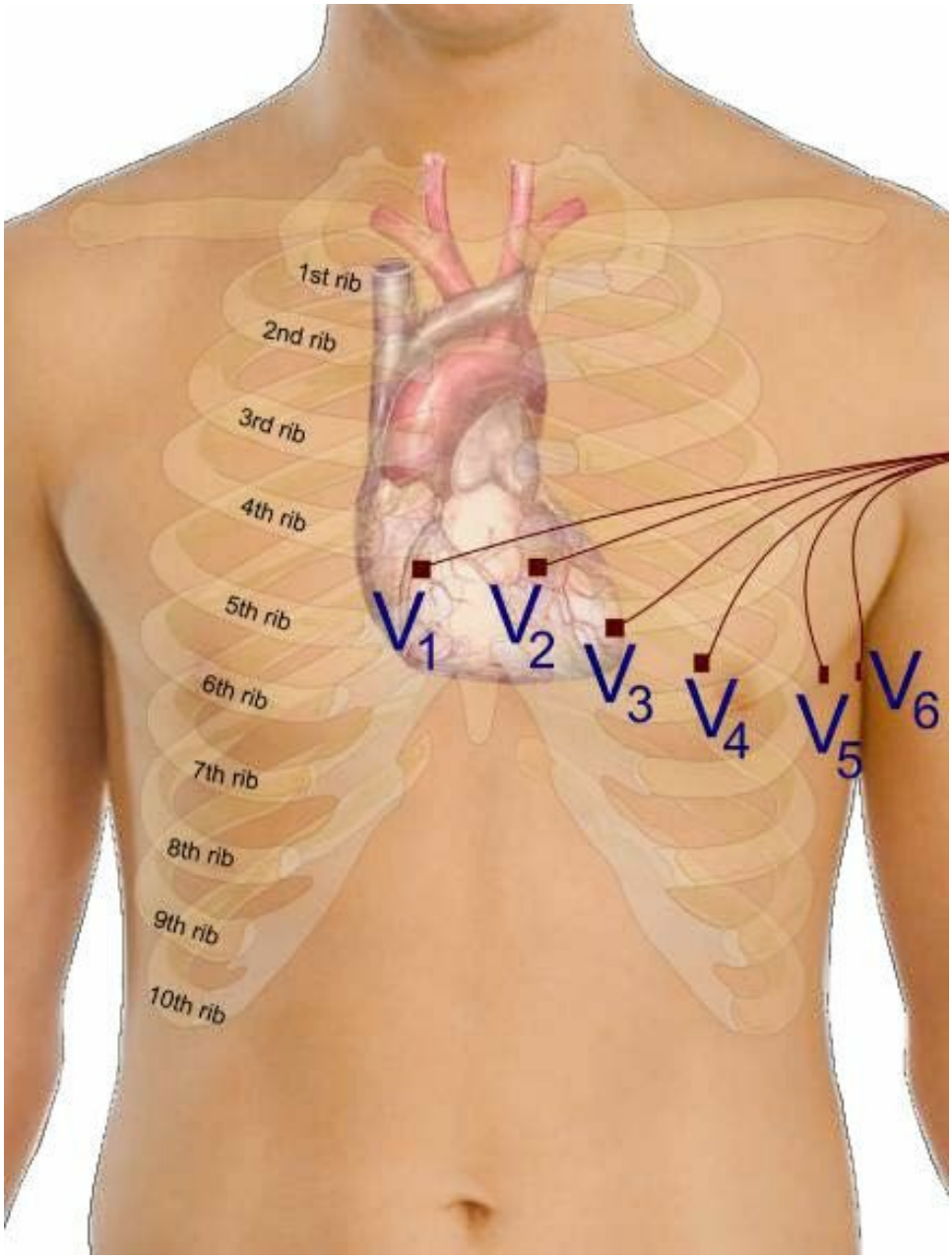
The baseline of the ECG is the line from the TP of one complex to the TP of another one. The PR segment should be on this line, but there are times when it is elevated.

Einthoven's Triangle



Willem Einthoven (1860-1927) was a Dutch doctor the physiologist who developed the technology for producing clinically useful ECG recordings and understanding biophysics. He received the Nobel Prize in Medicine for doing so.
Beginning at the SA node, the wave of depolarization spreads downward diagonally from right to left, as pictured. ECG leads viewing the approaching depolarization wave will have upright QRS-T wave complexes (aVL, I, II, aVF, III). The QRS-T wave complex in aVR will usually

appear inverted since that lead sees the depolarization wave moving away.
Roman numerals and letters designate limb leads **I - II - III - aVR** (augmented vector right) - **aVL** (augmented vector left) / **aVF** (augmented vector foot). In addition to limb leads, six skin electrodes are attached to the chest. Four limb leads and six chest leads produce the 12 lead ECG tracing. Augmented vector terminology refers to directional electrical forces at play during the cardiac cycle.
Chest leads are designated V1-V2-V3-V4-V5-V6. The following picture shows the placement of chest leads. These leads view the heart in the horizontal plane from front to back.



Keep in mind that this arrangement of skin-electrode placement is typical for a standard 12 lead

ECG. However, certain clinical situations may warrant repositioning electrodes to evaluate other cardiac abnormalities. For example, when a patient suffers blockage of the right coronary artery and subsequent right ventricular infarction, position chest electrodes on the *right* side of the chest to demonstrate more clearly right ventricular STEMI. To evaluate a posterior wall myocardial infarction that may be easily missed, place electrodes on the back of the chest to reveal characteristic ST-segment elevation not seen in anterior chest leads.

Interpreting the ECG takes some practice because there's a lot going on in the graph. It is important that you understand everything you read here. You don't have to memorize everything, but do keep notes or this book handy.

When you have an ECG to interpret, look at it broadly and take note of any outstanding features. Do not dwell on the tiny details at this point but try to form a general impression about it. Does it seem like a case of arrhythmia, ischemia, etc.? Keep your tentative conclusion in mind as you go through the next steps.

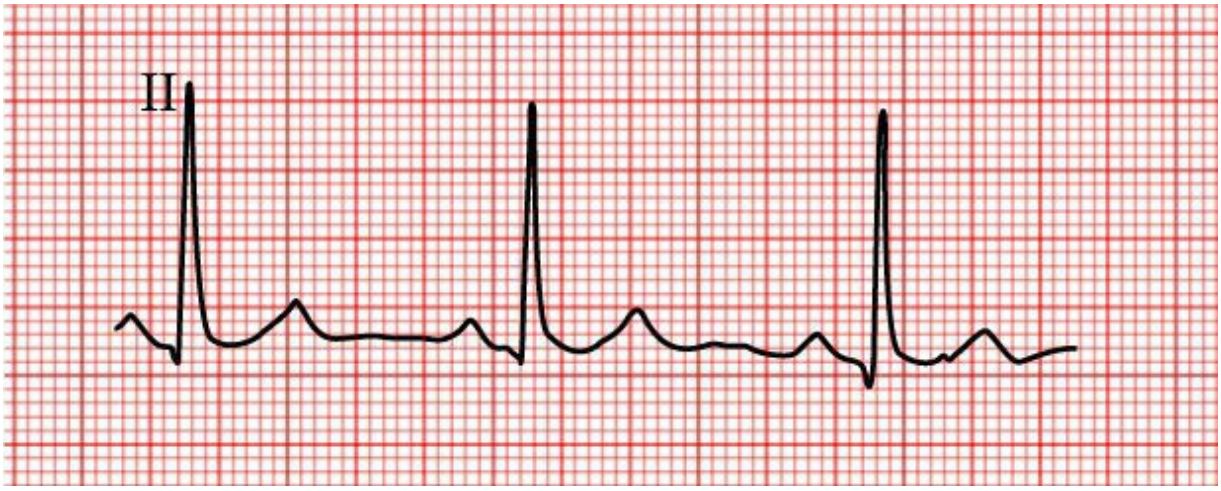
An ECG gives a lot of information that is only unlocked if you know what each part of the tracings means. In general, a normal reading has the following characteristics:

Reading is considered abnormal when these are present:

After gaining an overview, go over the ECG sequentially. Determine where the normal and abnormal beats are. For the normal ones, evaluate the axis, intervals, blocks, and other things you need to find out. For the abnormal beats, think about what may be causing them.

Before anything else, you must know that the above features are just general indicators of normality and abnormality. If you want to get useful insights, you have to consider other features. Read on to know how to get specific information from ECG readings.

Rate



There are several ways the rate can be determined. The most often used is to count the number of large squares between subsequent QRS complexes and divide 300 by this number. This works because there are 60,000 milliseconds in a minute, and each large square represents 200 milliseconds. 60,000 divided by 200 gives 300. Thus, if there were only one large square between two subsequent QRS complexes, the rate would be 300 beats per minute. If there were two, the rate would be 150 beats per minute and so on.

This method is valid only if the rhythm is regular. In a like manner, a more precise rate can be determined by dividing the number of small squares into 1500. This works because there are five small squares for each large square (3 x 5 =1500). Again, this method is valid only if the rhythm is regular. When the rhythm is irregular, it is better to use more than two QRS complexes to determine the rate. The easiest method is to count the number of intervals in a six-second time period and multiply by ten to obtain the heart rate in beats per minute.

Many monitoring systems display a six-second sweep to make use of this technique. On an EKG, there are usually three-second markers. The number of QRS complexes between two of these multiplied by ten gives the heart rate in beats per minute.

The ECG is traditionally 10 seconds long, with each lead covering 2.5 seconds. The paper has three to four strips. The top three strips have 12 leads.
Bear in mind that the vertical height of a segment or wave is measured by millimeters, while the width is measured in milliseconds. This is because the width of the tracing reveals the duration of the electrical activity, while the height shows its voltage.
Some ECG devices calculate the heart rate on their own, but they may be inaccurate, especially when the waveforms are abnormal. It is always better to know how to make calculations manually.
There are many ways to compute the rate of the heartbeat:
Check: is the heart rate faster or slower than expected? Again, the normal heart rate is 60-100 beats per minute, but this may vary according to the patient's age and other health conditions.
You can already make a diagnosis based on heart rate:
For adults, the standard rate is at 60 – 100 beats per minute (BPM). If the rate is greater than 100 BPM, tachycardia is present. If it is less than 60 BPM, there is bradycardia.
Children normally have faster heart rates than adults because of their smaller body sizes. Anything faster than the values given below counts as tachycardia; if slower, then it is bradycardia.

Rhythm

The heartbeat rhythm is more easily studied by using a rhythm strip, which is most often a 10-second recording from Lead II (if you used a 12 lead ECG). Look into the other leads as well to make a more accurate diagnosis about the rhythm.
One of the easiest things to determine from the rhythm is whether it is slow or fast (bradycardia or tachycardia) and whether it's irregular or regular.

Measuring Rhythm

There are two ways to measure rhythm: ***Using a piece of paper and pencil***: Place the paper along the baseline. Move it up so that the edge is near the R wave's peak. On your paper, mark the R waves of two consecutive QRS complexes to get the R-R interval. Transfer the paper across the ECG tracing and see whether the following R-R intervals line up with your marks. If yes, you can say that the ventricular rhythm is regular. If not, it is irregular. Do the same for the P waves (P-P intervals) to know whether the heart's atrial rhythm is regular or irregular.
Using calipers: Place one point of your caliper on the peak of an R wave. Adjust the calipers so

that the other point lands on the next R wave. This gives you the R-R interval. Swivel the calipers to check whether it falls on the third R wave's peak. If they do, the R-R (ventricular) rhythm is regular. If not, it is irregular. You can also determine the atrial rhythm this way by measuring the P-P interval.

If the heartbeat has a regular rhythm, count how many complexes there are on the rhythm strip. This is usually 10 seconds long. Multiply six by this number to get the average number of complexes per minute.

An irregular heart rhythm may be regularly irregular, with a recurring pattern of irregularity, or irregularly irregular, which means that the rhythm is totally disorganized.

Is the rhythm grouped or ungrouped? Abnormal heart rhythms have grouped beats.

Check whether the rhythm is wide or narrow. This means observing the average width of the QRS complexes. If it is wide, there may be a conduction problem coming from the ventricles or from the supraventricular region (above the ventricles). If narrow, the abnormality may exist in the sinus node, atria, or junctional region.

Look for P waves – if you can't find them, the patient may be experiencing atrial fibrillation or sinus arrest.

If they are present, check the ventricular and atrial rate. Are all P waves similar to each other? They are expected to be the same if there is a 1:1 conduction to the QRS complexes.

Abnormal ratios between P waves and QRS complexes may indicate atrioventricular dissociation (AV dissociation). In complete AV dissociation, the atrial and ventricular electrical activities always occur separately. In incomplete AV dissociation, capture beats show up infrequently.

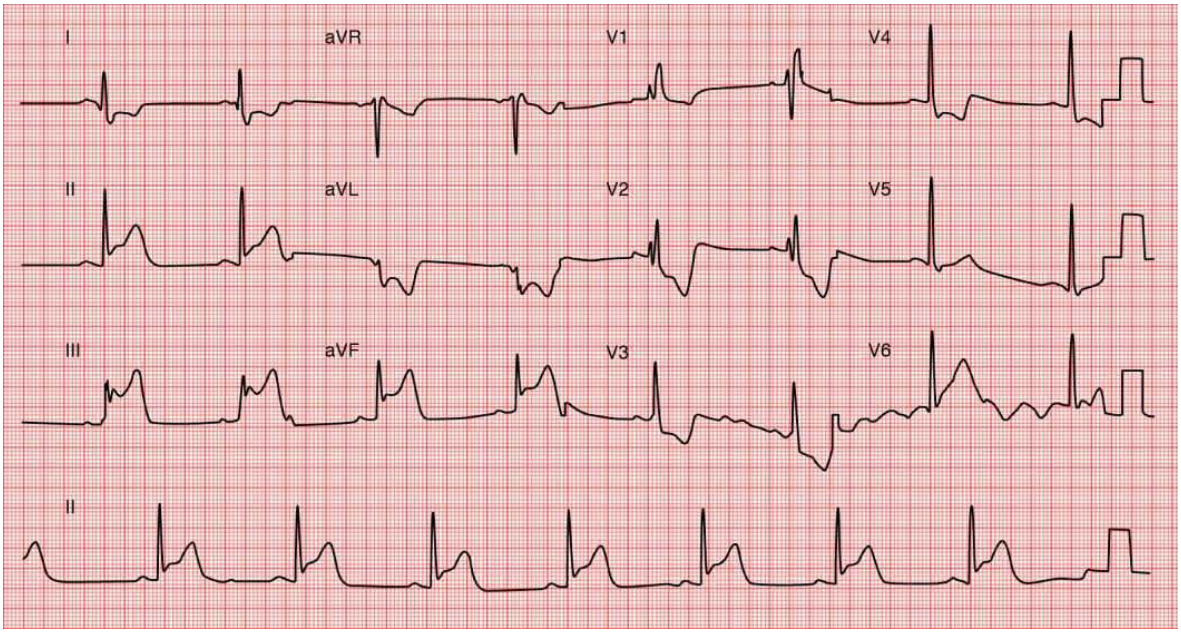
If there is an abnormality in P wave shape and PR interval, this suggests that there is something wrong with the conduction of the sinus, atria, junction, or ventricles. You will know the location depending on which leads the abnormalities show up.

If the heartbeat is irregular, compute for the range. Inspect the PR, QRS, QTc, PP, and RR intervals. Observe if there are irregularities in the intervals.

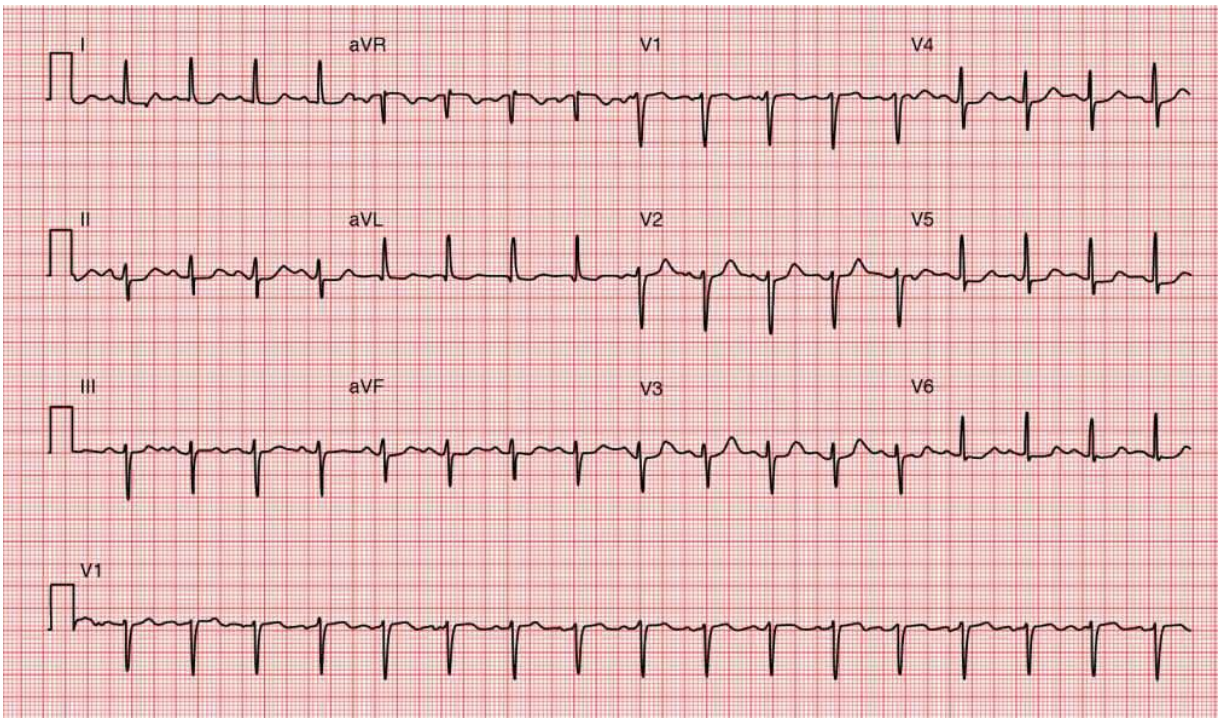
Consider onsets and terminations. If they are abrupt, a re-entrant process may be causing them. If gradual, it is possible that an area of the heart has increased automaticity (ability to conduct impulses).

There are a lot of heart problems that can be diagnosed by heart rhythm type:

Bradycardia



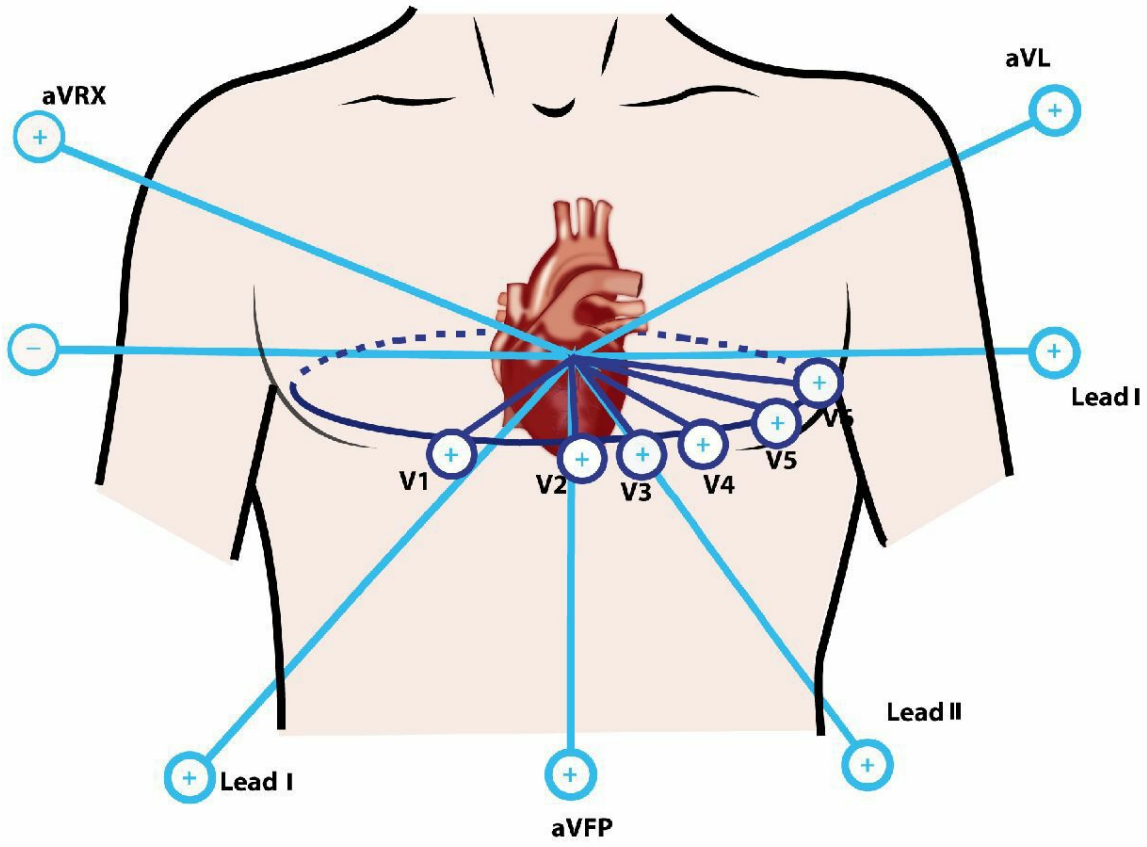
Sinus Bradycardia: Note that the rate is about 45 bpm.



Sinus Tachycardia: Note that the rate is more than 100 bpm.

Axis

Heart axis



Electrical impulses are vectors that have energy and direction. Vectors add up when they head towards the same direction, decrease in energy and change their direction when they are going in opposite locations, and add or subtract energy and change directions when they meet at an angle. The heart has numerous vectors, but as mentioned, they all combine to produce major currents. All these vectors together are referred to as the electrical axis.

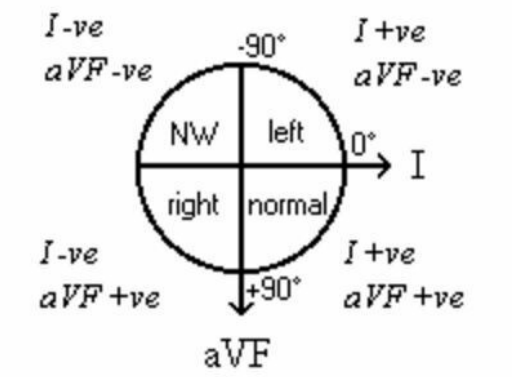
There are a number of vectors detected by the ECG electrodes: The P-wave vector, T-wave vector, ST-segment vector, and QRS vector.

Electrodes pick up electrical activity. When a positive electrical impulse moves away from an electrode, the ECG registers it as a negative or downward wave. When a positive wave approaches an electrode, the ECG transforms it into a positive or upward wave. When the electrode sits at the middle of a wave, the ECG demonstrates a positive wave for the energy coming towards it and a negative wave for the energy retreating from it.

These electrodes are placed at specific angles to the main axis to get a three-dimensional view of the heart's electrical activity.

Just like with heart rate and rhythm, the electrical axis is affected by abnormalities. This is why the electrical axis is studied in the ECG.

As you may recall, the QRS complex stands for ventricular depolarization. This is the strongest impulse in the heart, and thus the QRS complex determines the heart's main axis.
The degree of the QRS axis will tell you whether it is normal or deviated:



Normal: between -30 to +90 degrees

These are some ways to determine the axis:
The quadrant method involves looking at leads I and aVF.

Lead I	**Lead aVF**	**Quadrant**	**Axis**
Positive	**Positive**	**Left Lower**	**Normal**
Positive	**Negative**	**Left Upper**	**Possible LAD**
Negative	**Positive**	**Right Lower**	**RAD**
Negative	**Negative**	**Right Upper**	**EAD**

The Isoelectric Lead Method is more precise than the method above and involves finding the isoelectric/equiphasic lead. This is the frontal lead that has zero net amplitude, meaning a QRS that is a flat line or biphasic, with R wave height that is equal to Q or S wave depth.
After finding the isoelectric lead, the next step is to find the positive leads – those with the highest R waves or biggest R to S ratios.
When this is done, the QRS axis is calculated by going 90 degrees to the isoelectric lead and pointing towards the positive leads.

Chapter 9. How to Read an ECG Trace

Steps in ECG Interpretation

1. Determine the **rhythm** and **regularity**
2. Calculate the **rate**
3. Evaluate **P wave**
4. Calculate **PR interval**
5. Analyze **QRS complex**
6. Examine **T wave**
7. Calculate **QT interval**
8. Look for **other** characteristics

Check the heart rate. Is it fast (tachycardia >100 bpm) or slow (bradycardia <60 bpm)? What is the rate? (calculate the rate by dividing 300 by the number of big squares between one R-R interval).
Check the rhythm. Is it regular or regularly irregular (i.e., a pattern to the irregularity) or irregularly irregular (no pattern – AF). If unsure of rhythm, place a piece of paper along with the ECG and mark the positions of 3 successive R waves. Move the paper along to see if the R waves on the paper match up with successive R waves on the ECG (if so, then it is regular).
Are there P waves? P waves normally precede each QRS complex. Normal length 0.12 – 0.2s or 3-5 small squares. Absent P waves can indicate AF or sinoatrial block. A disconnection between P waves and QRS can indicate heart block.
Does a QRS complex follow each P wave? Check duration and voltage (height). Normal duration <0.12s or three small squares. >0.12s can indicate ventricular conduction disorders such as bundle branch block. Large (tall) QRS complexes can indicate ventricular enlargement.
Check the ST segment. Is it on the isoelectric line? Is it elevated or depressed?
Check the QT interval. Measure from the start of QRS to the end of the T wave. (QTc <0.44s).
Check the T waves. Normal T wave is inverted in aVR, V1, and sometimes V2. It is abnormal if the T wave is inverted in I, II, and V4-6. It can be “peaked/tented” in hyperkalemia and flattened in hypokalemia.
Check for extra beats. Extra beats may be found in abnormal heart rhythms. Ectopic beats can be a normal finding in some patients.

Steps in 12 lead ECG Interpretation

1. **R**hythm
2. **A**xis
3. **B**undle branch block
4. **E**nlargement of chamber

5. **I**schemia or infarction
6. **O**ther abnormalities

Summary of 12 lead EKG Interpretations

Rate and Rhythm	• Six second method • Counting small box method • Presence of PQRST and its characteristics • Look for intervals		
Axis	look at lead **I** and **aVF** (*consider entire QRS complex for axis determination*)		
	Vertical axis (Consider Lead **I** and **aVF**)	Normal axis	Lead **I** and **aVF** positive
		Right axis	Lead **I** negative and **aVF** positive
		Left axis	Lead **I** positive and **aVF** negative
	Horizontal axis (Look at **V1**, **V2** and **V5**, **V6**)	Anterior axis	Positive **V1** and **V2**
		Posterior axis	Positive **V5** and **V6**
Bundle branch block	• Look at lead **I**, **V1** and **V6** (*only last half of the QRS complex*) • It require QRS duration > 0.12 sec		
	RBBB	Negative lead **I** and **V6** and positive **V1**	
	LBBB	Negative lead **V1** and positive lead **I** and **V6** (R or R')	
Hemiblock	look at lead **I** and **aVF**		
	Left anterior hemiblock (LAHB)	Left axis deviation	Lead **I** positive and **aVF** negative
		qR complex in the lateral limb leads	Lead **I** and **aVL**
		rS complex in the in inferior leads	Lead **II**, **III** and **aVF**
		Delayed intrinsicoid deflection (time for R wave peak)	In aVL >0.45 seconds
		Do not diagnose LAHB in presence of inferior infarct (prominent **Q** in lead **II**, **III** and **aVF**)	
	Left posterior hemiblock (LPHB)	Right axis deviation	lead **I** negative and **aVF** positive
		rS pattern in lead **I** and **aVL** tall R waves in **II**, **III** and **aVF**	This goes with right axis deviation
		Looks similar to **S1Q3T3** pattern as in pulmonary embolism	
Chamber enlargement	**Right atrial enlargement**	Narrow and tall **P** wave in lead **II** and **V1**	P pulmonale
	Left atrial enlargement	Wide P wave with notching in lead **III**, **aVF** and **V1**	
	Right ventricular hypertrophy	Tall **R** waves in **V1**, **V2** and deep **S** waves in **V5** and **V6**	
		Right axis deviation	Negative lead **I** and positive **aVF**
	Left ventricular hypertrophy	Left axis deviation)	(Positive lead **I** and negative **aVF**
		Down sloping **ST** and inverted **T** wave in lateral leads	LV Strain pattern
		R in **aVL** plus **S** in **V3** > 28 mm in men and >20 mm in	Cornell criteria

Summary of 12 lead EKG Interpretations- Cont…

Ischemia	**ST** segment depression and **T** wave inversion	Lead **I**, **aVL**, **V5** and **V6**	Lateral wall (Left circumflex artery)
		Lead **II**, **III** and **aVF**	Inferior leads (Right coronary artery)
		Lead **V1**, **V2**, **V3** and **V4**	Anterior wall (LAD territory)
Infarction	Acute myocardial infarction	**ST** segment elevation in the target area with **ST** segment depression and **T** wave inversion in the opposite area	Reciprocal changes
	Old myocardial infarction	Presence of large **Q** waves in target areas	At least > 1 mV
Other abnormalities	Pulmonary embolism	Prominent **S** in lead **I**, **Q** wave and inverted **T** wave in lead **III**	S1Q3T3 pattern
		Right ventricular strain pattern	**ST** depression in **V1-V3**
		Sinus tachycardia	
		New incomplete RBBB	
	Hyperkalemia (depending on serum level)	Tall peaked **T** waves	
		ST segment depression	
		Various bundle branch block	
		Severe bradycardia with AV block	
		V tach/V-Fib	
	Pericarditis	**PR** segment depression	
		Generalized **ST** segment elevation	
	Hypocalcaemia	prolonged **QTc**	
		Flat or inverted **T** waves	
		Prolonged **ST** segment without increase in **T** wave duration	
	Hypercalcemia	Short **QTc**	
		PR segment prolongation	
	Hypomagnesaemia	Peak **T** wave	
		Prominent **T** wave	
		prolonged QRS	
		ST segment depression	
		Polymorphic ventricular tachycardia	
	Pericardial effusion or Cardiac tamponade	Low voltage EKG	
		Electrical alternance	Beat to beat change in amplitude

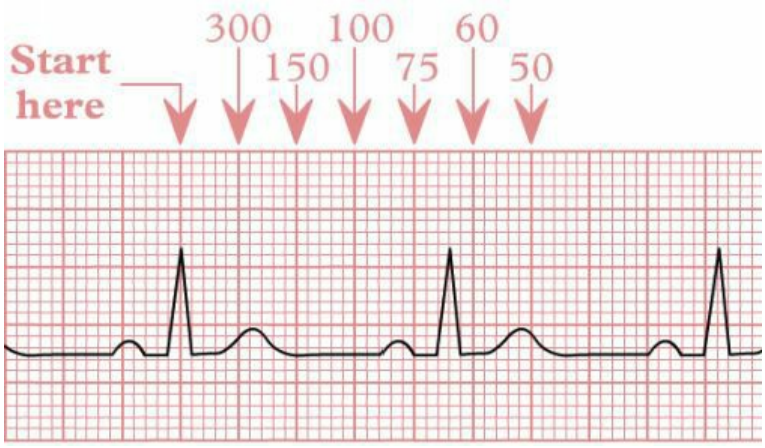
Chapter 10. How to Determine Heart Rate

When interpreting the EKG, it is crucial to have a systematic approach. The five main areas you need to master in order to interpret EKG effectively are rate, rhythm, axis, block, and infarction. In this section, we will cover how to calculate the heart rate.

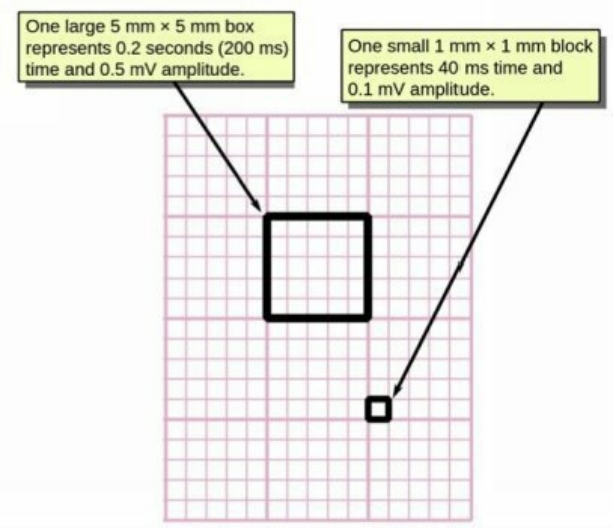
The heart rate is easily calculated from the EKG using this simple three-step method. Firstly, however, it is essential to remember that one small square on EKG paper represents 0.04 seconds and one large square (made up of five small squares) represents 0.2 seconds.

Calculate the heart rate by:

1. It is finding an R wave that falls on a heavy line that comprises a large box.
2. Then count until the next R wave, the number of large squares.
3. Finally, the boxes are counted, and the rate is determined accordingly by beats per minute (bpm).



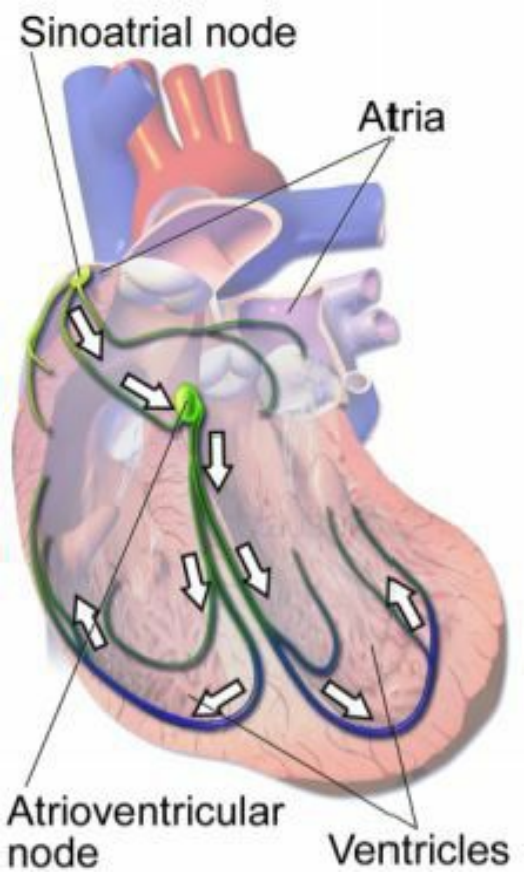
If the next R wave falls on the third thick line, the patient's heartbeat would be 100bpm. A heart rate between 60 and 100bpm with an upright P wave indicates that the impulse is being generated from the sinus code. If the next R wave does not fall on a thick black line, you can accurately estimate the heart rate by counting the small boxes and remembering that each small box represents 0.04 seconds.



By determining the bpm, you will also be able to identify the focus of the beat. Although every cell in the heart can technically initiate action and stimulate the heartbeat, only a few areas do so on a regular basis: the sinus node, the AV node, and the ventricles. The sinus node is the fastest focus.

However, the slower impulse will always be overdriven by the fastest pacemaker that sets the pace. Note also that impulses that are generated from the AV node or from the ventricles will not have a P wave as the presence of the P wave indicates sinus node activity.

It is also important to note that the lower down the focus in the conduction system, and therefore the more prolonged the QRS, the less reliable and the less stable it is.



The above method for calculating the heart rate does not work for rates that fall below 40 bpm. Another way to calculate the heart rate is by following the steps below:

1. Count the 3-second intervals, which you will find at the bottom of every EKG strip.
2. Count the number of cycles within these intervals (which will amount to 6 seconds in total).
3. Then multiply this by 10 (10 x 6 second = 1 minute) to accurately calculate the beats per minute.

An impulse that is generated from below the sinus node (i.e., impulses that are initiated from the AV node and the ventricles) is called a junctional rhythm. The absence of the P wave is representative of a junctional rhythm. Junctional rhythms are often related to overmedication. The nurse should, therefore, always examine the patient's medications whenever they note the junctional rhythm on EKG. The following drugs necessitate close examination in the presence of junctional rhythms: antiarrhythmic medications, beta-blockers, calcium channel blockers, and digoxin.

Before learning how to evaluate the rhythm, it is important to recap and remember the following fundamentals:

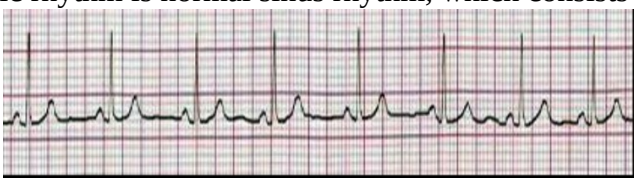
- The normal heart rate is **60 – 100 bpm**.

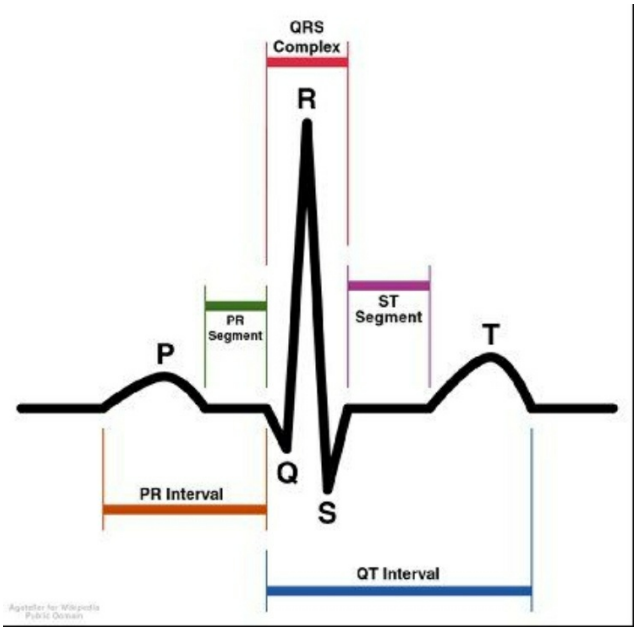
- A slow heart rate below 60 bpm is referred to as **bradycardia**.
- A fast heart rate above 100 bpm is referred to as **tachycardia**.

Chapter 11. Arrhythmias in the ECG

Normal Sinus Rhythm

Before we start to analyze any ECG, we need to establish what a basic rhythm looks like. The basic rhythm is normal sinus rhythm, which consists of a P-wave, QRS complex, and a T wave.

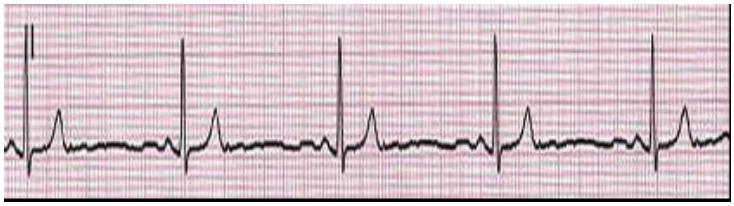


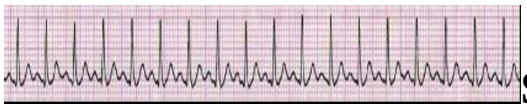


The T wave represents ventricular re-polarization or getting the cells ready for another depolarization.
The PR interval is the time interval between the P wave and the onset of the QRS, which reflects the time between the sino-atrial (SA) node and ventricular depolarization. The normal duration is between 3 and 5 small squares (0.12 - 0.2 seconds).
The SA node is responsible for (in normal sinus rhythm) atrial depolarization. The AV node (in normal sinus rhythm) initiates ventricular depolarization.

Sinus Bradycardia

This rhythm is the same as normal sinus rhythm. However the rate is less than 60 beats per minute.



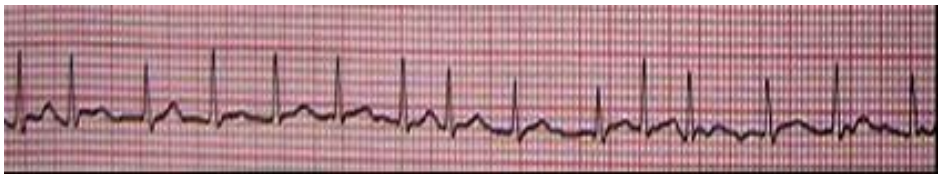


Sinus Tachycardia

This rhythm is the same as normal sinus rhythm, but the rate is greater than 100 beats per minute.

Atrial Fibrillation

Atrial fibrillation simply refers to the atria fibrillating or quivering. Atrial fibrillation is characterized by a lack of definitive P waves. The QRS complexes and T waves will be present. However, the rate of the rhythm will be irregular, generally somewhere between 120 to 160 beats per minute. It is, however, possible for atrial fibrillation to be slower than 120 beats per minute. However, it is less common. Slow atrial fibrillation can range from rates between 50 and 120 beats per minute.

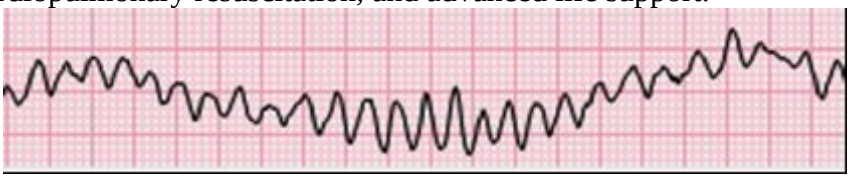


So, to follow the method, I determine that there are no definitive P waves. There are QRS complexes and T waves; the rhythm is irregular, and it is irregularly irregular.
Actual fibrillation is a phenomenon where an overexcited area of the atria is firing at anywhere around 300 beats per minute. Although the atria are firing at this rate, the AV node will not allow all the impulses to depolarize the ventricles. The atrial activity does not look like normal P waves as the electrical impulse is originating from somewhere within the atria and not following the normal conduction pathway.
The normal conduction pathway originates from the SA node to the AV node, down the Bundle of His, bundle branches, and through to the Purkinje fibers. The normal conduction pathway consists of myelinated fibers which transmit impulses at incredibly fast speeds. This is displayed by narrow complexes, for example, the QRS complex, within three small squares or 0.12 seconds. If an impulse originates outside of the normal conduction pathway, the complexes would be broad and bizarre in appearance. In atrial fibrillation, the atrial activity is so fast that it may not be seen on the ECG, and if it is seen, they resemble nothing like the normal P waves. In fact, these atrial depolarizations are generally referred to as f waves.

Ventricular Fibrillation

Ventricular fibrillation, like atrial fibrillation, refers to the ventricles quivering. A hugely significant difference between atrial fibrillation and ventricular fibrillation is that ventricular

fibrillation is a life-threatening rhythm that needs emergency treatment in the form of electrical cardioversion, cardiopulmonary resuscitation, and advanced life support.

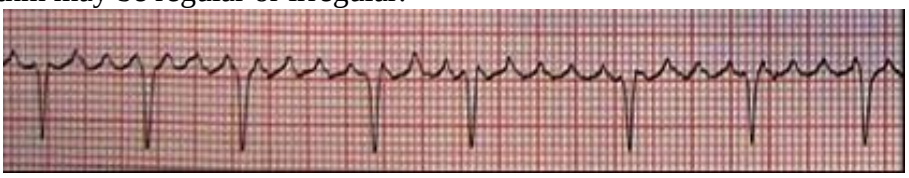


Ventricular fibrillation is shown as an unsystematic wiggling, jagged, spiky appearance. The rhythm should be confirmed by checking the ECG leads are attached properly to the patient. Giving the patient a brief but definite shake at this point would also not be frowned upon! They should be no P-wave, QRS complexes that are unrecognizable from how it should appear, and no definitive T wave.

The reason ventricular fibrillation is a life-threatening rhythm is that the ventricles are the main pumping chambers within the heart, and if they are made ineffective, there will be no circulating volume to the rest of the body, and subsequently, death will follow if not rapidly treated. With atrial fibrillation, the atria only supply 10-30% of the cardiac output, so if the atria are not pumping as normal, the body can overcome it. However, if the ventricles aren't pumping properly, nothing can overcome that besides emergency lifesaving intervention.

Atrial Flutter

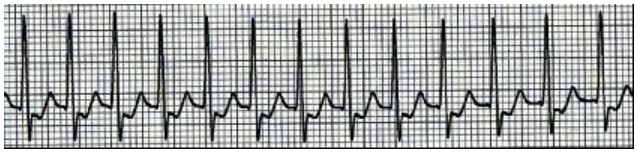
Atrial flutter is a rhythm that has definite P waves (which in atrial flutter are actually referred to as F waves), which are saw–tooth in appearance. There are QRS complexes and T waves. The ventricular rhythm may be regular or irregular.



Intrinsically with atrial flutter, again, there is overexcitation of the atria. However, differing from atrial fibrillation, atrial flutter is where the atria are depolarizing continuously and regularly, which gives the saw-tooth appearance.

Atrial or Supraventricular Tachycardia

A supra-ventricular tachycardia (SVT) is basically any tachycardia that originates from above the ventricles (hence supra), so in theory, sinus tachycardia is an SVT as the rhythm is originating from the SA node. An SVT will usually have a narrow (≤0.12 seconds or three small squares) QRS complex unless the patient has a bundle branch block or aberrant conduction. If an overexcited area of the atria is firing and then the impulse travels down the myelinated fibers, the impulse then passes through the AV node, and the ventricles depolarize at a rapid rate. Because the impulse is traveling down the myelinated pathways and through the AV node, the impulse is traveling very quickly, so the QRS complexes are narrow.



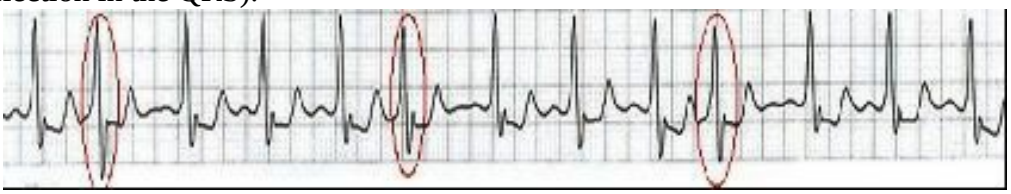
Ventricular Tachycardia

Ventricular tachycardia, in theory, should have a P wave in it. However, in practice, this is hard to see. The QRS complex will be uniformly spiky or uniformly rounded in appearance and will have a definite shape that repeats itself, which is very unlike ventricular fibrillation. If an ECG is taken, there should be broad ventricular complexes >0.14 seconds, with upright QRS in V1 and negative in V6. In addition, there should be an extreme left axis deviation. There is a T wave, but again, this may not be seen. The treatment of this will depend upon whether the patient has a pulse or not.

Extrasystoles

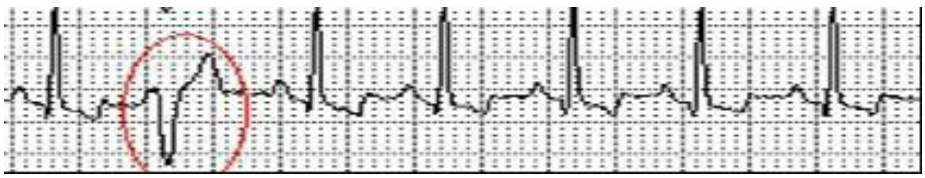
Atrial Ectopics / Supra-Ventricular Extrasystole

Atrial ectopics are early beats that originate from the atria. Basically, what you will see is a P wave that is not exactly the same shape as the other P waves that comes earlier in the rhythm than expected, followed by a QRS, T wave, and then a compensatory pause. Because they originate from within the atria and not from the SA node, they will take longer to depolarize the atria, and as such, the shape will be broader than normal - although it may not be a noticeable widening. In the following example, the P wave is actually hidden in the R wave (the first initial upward deflection in the QRS).



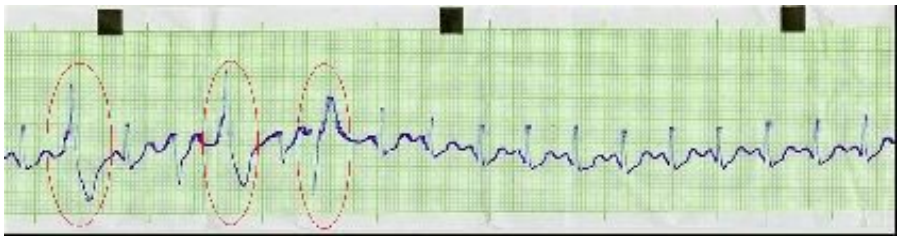
Ventricular Ectopics / Ventricular Extrasystole

Ventricular ectopics are simply early ventricular beats that do not originate from the AV node. As such, the depolarization takes longer, and the QRS is, therefore, wider (>0.12 seconds or three small squares) and more bizarre in its morphology. The patient may, or may not, have a pulse with the ventricular ectopic. In the following example, if this ectopic or extrasystole occurs again and is the same shape, it would be called mono or uni-focal in origin.



Polymorphic or Multifocal ventricular Ectopics / Extrasystoles

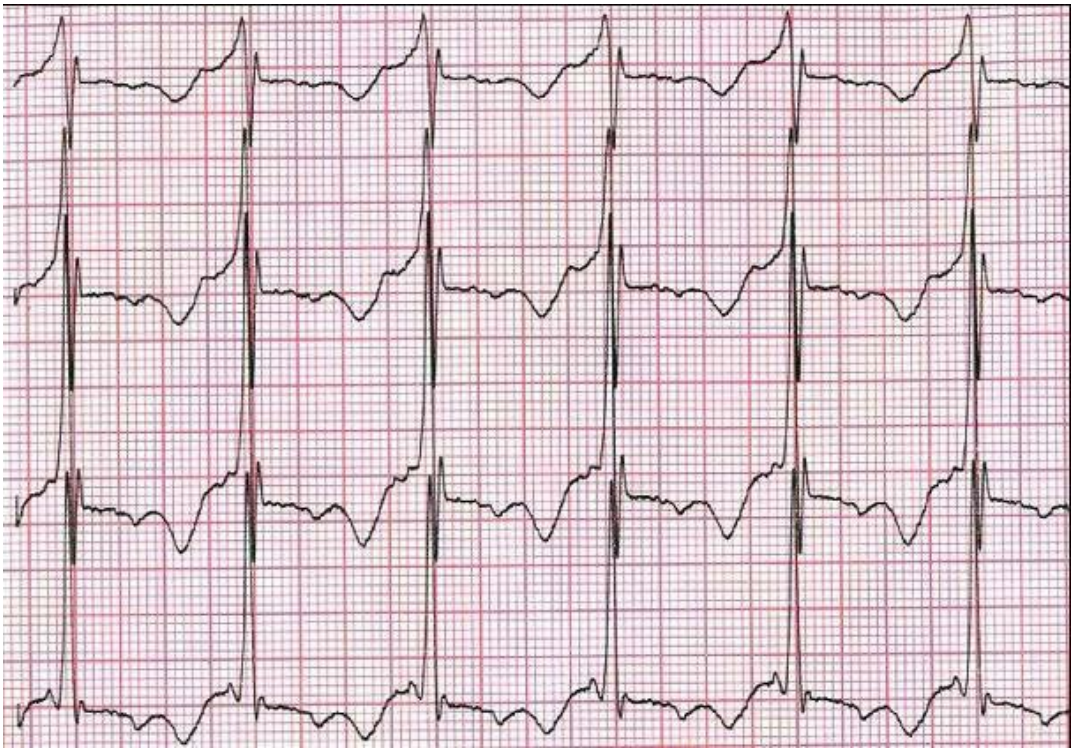
These are ventricular pre-excitation which occur from differing areas of the ventricles. The QRS is again broad and bizarre when the ectopic/extrasystole occurs, but they are different shapes, as the depolarization is originating from differing areas of the ventricles, as is shown in the following example.



BAV: Atrioventricular Block

I Degree

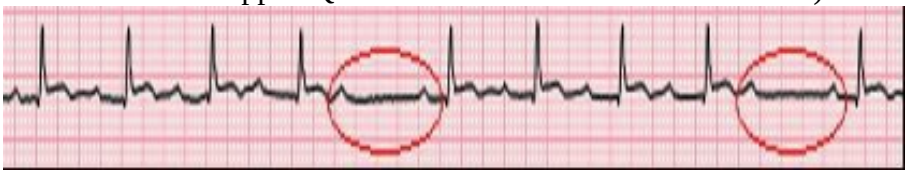
First-degree heart block is very simply a lengthened PR interval greater than five small squares or 0.2 seconds. This rhythm is often a sign of a diseased AV node. However, it is also seen in myocarditis, electrolyte disturbances and sometimes following certain drugs that increase the refractory time of the AV node (including but not limited to calcium channel blockers and beta-blockers). This rhythm is benign. However, people in a first-degree heart block are more likely to develop into a second-degree heart block if they are given certain anti-arrhythmic medications. In the following example, the first two lines show the most obvious first-degree heart block.



II Degree

Second-degree heart block Mobitz type 1 / Wenckebach

Second-degree heart block (type 1) is also known as Wenckebach, after its founder Karel Frederik Wenckebach in 1899. It is nearly always due to a diseased AV node. This rhythm is basically a progressive lengthening of the PR interval until there is a P wave with no QRS depolarization followed by another P wave, a QRS complex, and a T wave. The PR intervals get longer and longer until the QRS is dropped. In the following example, there is a 4:1 block (4 conducted QRS beats and one dropped QRS beat as shown with the red circles).



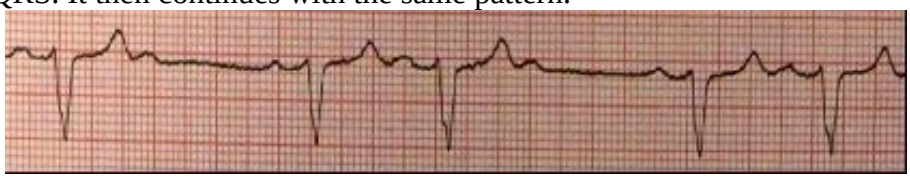
If you ever see a P wave not followed by a QRS depolarization and another P wave, then you have a second-degree heart block at the very least.

Second-degree heart block Mobitz type 2

With second-degree heart block (type 2), there is often a normal intrinsic beat with P, QRS, and T waves, followed by a P wave, no QRS, and then another intrinsic beat. If this pattern continues, it would be classed as a second-degree heart block (type 2) with a 1:1 block. The 1:1 block refers to 1 normal beat: 1 dropped QRS.

It is, however, more common to see a second-degree heart block (type 2) with a 2:1 (as shown

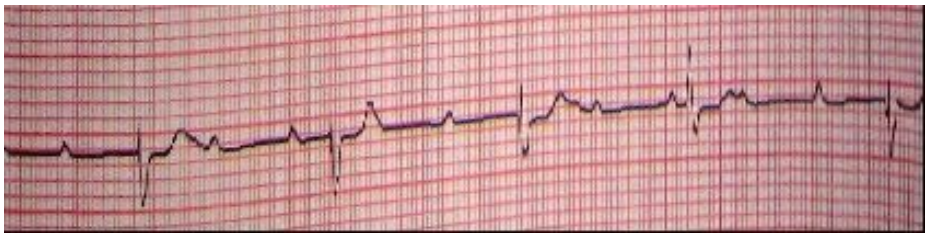
below) or a 3:1 heart block. This is basically two or three normal intrinsic beats, followed by a P wave with no QRS. It then continues with the same pattern.



It is also possible and not too uncommon to have a second-degree heart block (type 2) with a variable block. So, in this instance, you may have one intrinsic beat with 1 dropped QRS, followed by three intrinsic beats and a dropped QRS, next followed by two intrinsic beats, and so on.

III Grade

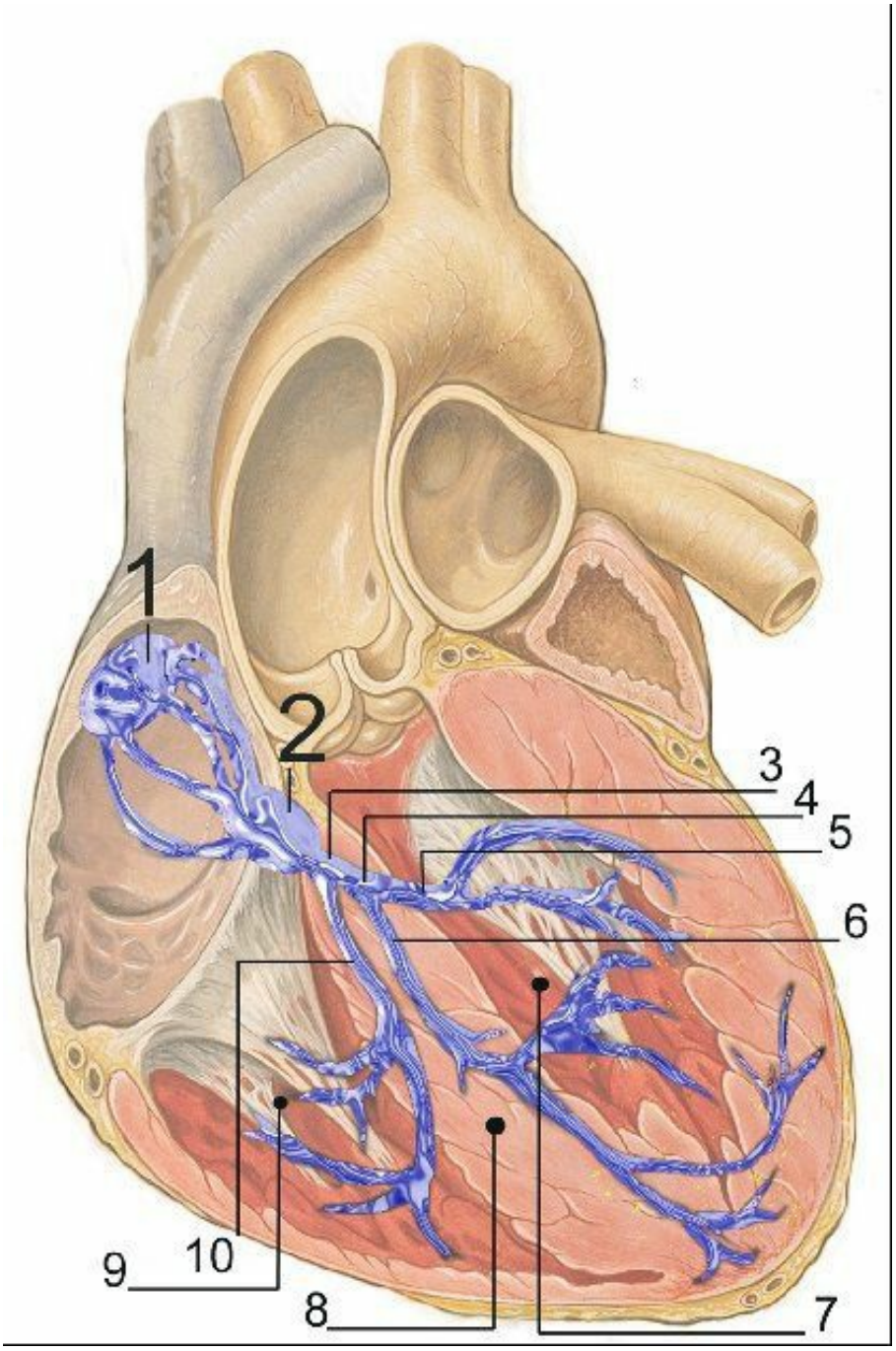
This rhythm is basically a disassociation between the atria and the ventricles, where the atria will depolarize at about 60-70 beats per minute, and the ventricles will beat at about 40 beats per minute. Both the atria (P waves) and the ventricles (QRS complexes) are regular in their respective rates, but they are not associated with one another; for example, atria at 60beats per minute and ventricles at 40 beats per minute. The following example shows the ventricular rate at approximately 30 beats per minute and the atria at approximately 75 beats per minute. Note the ventricular rate and atrial rate are different.



Often patients with this rhythm are unstable and need urgent cardiac pacing.

Left and Right Branch Block

Below is an image of the heart with the associated conduction structures:



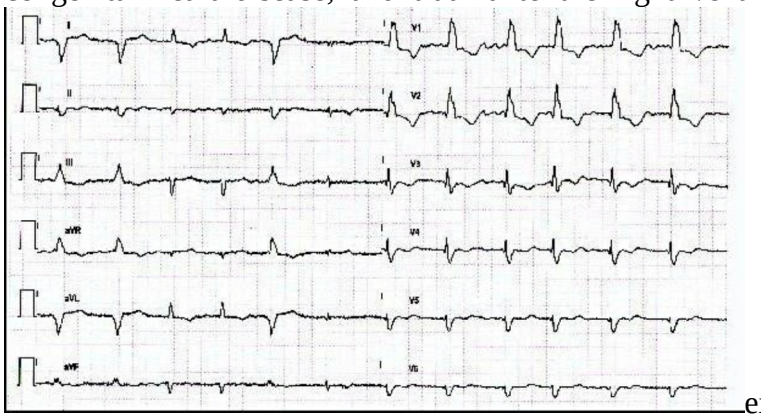
1. SA node
2. AV node
3. Bundle of His
4. Left bundle branch
5. Left posterior fascicle
6. Left anterior fascicle

7. Left ventricle
8. Ventricular septum
9. Right ventricle
10. Right bundle branch

Left bundle branch block

This morphology happens because the left bundle branch is unable to conduct impulses. Bundle branch blocks are easy to remember. If you can remember the words “William” and “marrow,” you will be halfway there. Very basically, with a left bundle branch block, there is a “W” shape in V1 and an “M” shape in V6 - hence “William.” The morphology does not exactly follow an M or W shape but comes close. To be more precise, there is a QS or rS in V1 and an RsR in V6. The non-capital letters reflect a small wave, and the capital letters refer to large waves. Bundle branch blocks must have a QRS, which is greater than three small squares or 0.12 seconds. Left bundle branch blocks are serious: if they are new, then it is possible that the patient has a myocardial infarction. However, it may also be due to aortic stenosis and dilated cardiomyopathies. The following example shows a left bundle branch block with atrial ectopics. Some authors believe that if you have a left bundle branch block, you, therefore, have a bifascicular block.

Right bundle branch block

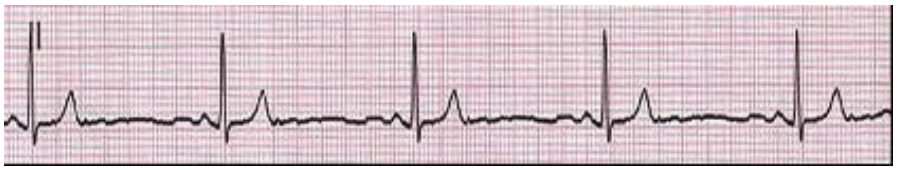
With the right bundle branch block, there is an “M” shape in V1 and a “W” shape in V6. To be more precise in the morphology of the right bundle branch block, an rSR is seen in V1 and qRS in V6. Remember that the QRS must be greater than 0.12 seconds or three small squares. Right bundle branch blocks are benign in their ECG alone. A right bundle branch block is often present when increased right-sided heart pressures are present, for example, with a pulmonary embolism, hypertension, cardiomyopathies, congenital heart disease, and trauma to the right ventricle. Again, the M and W shape is not 

exact but comes close.

PEA: Pulseless Electrical Activity

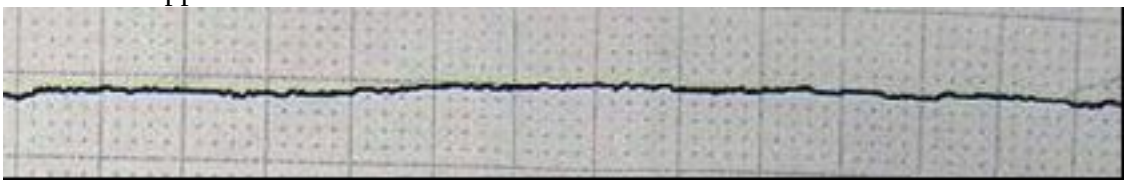
Electro-Mechanical-Dissociation / Pulseless Electrical Activity is another life-threatening rhythm

where cardiopulmonary resuscitation and advanced life support are needed. It is shown by any life-sustaining rhythm. However, there is no pulse associated with it. An example of this would be sinus bradycardia on the monitor accompanied by a lack of pulse.



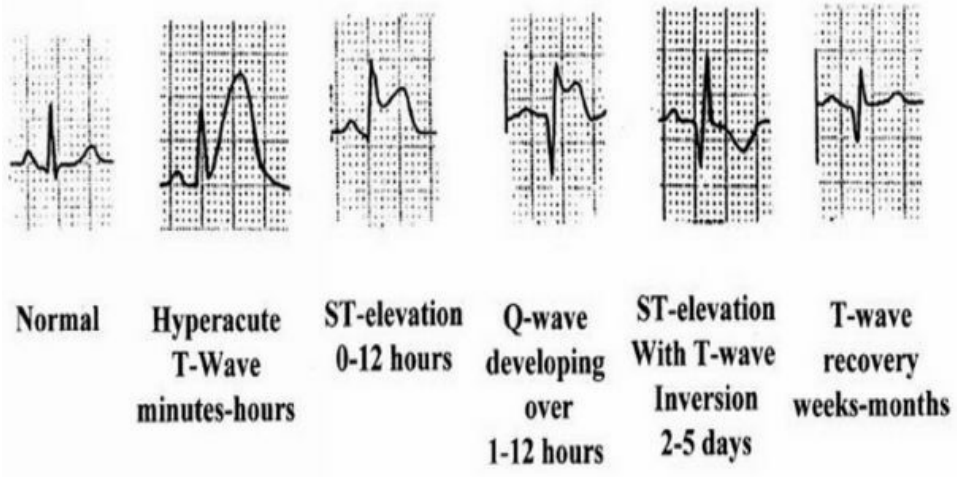
Asystole

Asystole is shown as no cardiac activity. No P, QRS, or T waves. The trace is often undulating in appearance and not truly a flat line. This trace needs to be confirmed in 2 ECG leads, and the amplitude, or ECG gain, should be turned right up to exclude fine ventricular fibrillation. This is another life-threatening arrhythmia that requires urgent cardiopulmonary resuscitation and advanced life support.

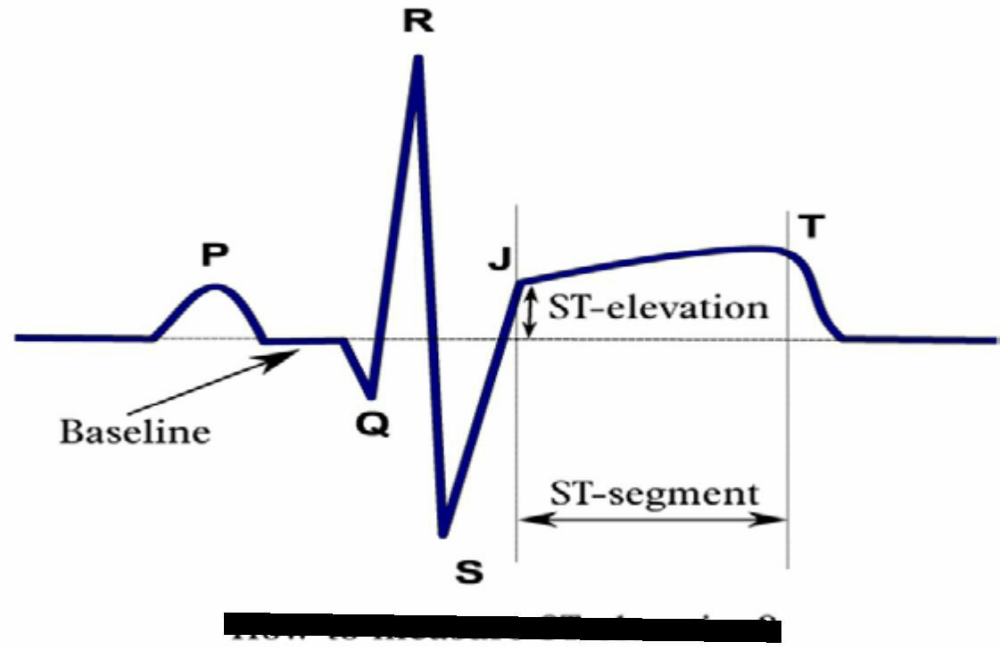


SCA / STEMI / NSTEMI

The earliest sign of myocardial infarction is a hyperacute T-wave followed by ST-segment elevation, T-wave inversion, and Q-wave formation.



The ST-segment returns to baseline. T-wave inversion persists and may deepen while Q-waves remain. The T-wave becomes upright eventually. This is also known as **STEMI** (ST-elevation MI)

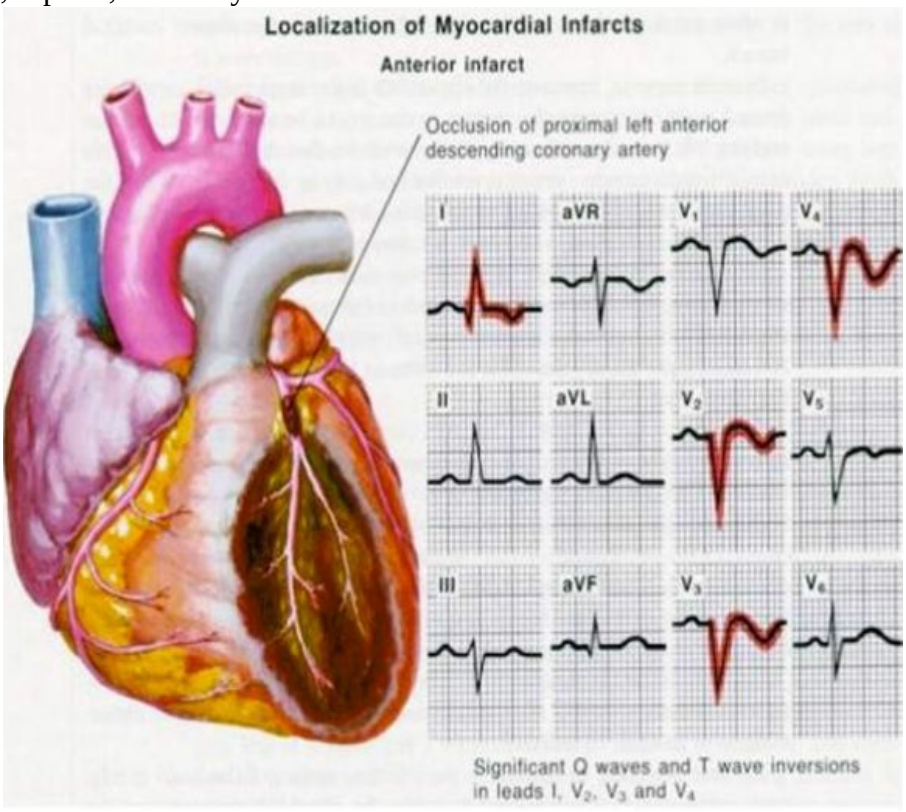


Chest pain with elevated ST segments in two anatomically contiguous (adjacent) leads on ECG, and elevated serum troponin confirms the diagnosis of myocardial infarction. However, a normal-appearing ECG and normal serum troponin do not mean the patient is healthy when in reality, patient history and symptoms suggest myocardial injury. In the very early stages of infarction, the initial ECG and serum troponin *may be normal*. In such instances, serial ECGs and troponin levels will be necessary to confirm the diagnosis.
Be aware, certain patient populations present with atypical symptoms.

- The atypical presentation may present with non-chest pain symptoms, such as weakness, nausea, sweating, cough, dyspnea, pain in the back, jaw, or head.
- Females, elderly individuals, and those with diabetes often present with atypical symptoms.
- Keep your index of suspicion for ischemia and/or myocardial infarction high when evaluating such patients and err on the side of caution when deciding whether to perform a 12-lead ECG.

NSTEMI (non-ST-elevation MI) presents as ST-depression and T-wave inversion. No progression to Q-wave exists, so this can also be called a **non-Q-wave** myocardial infarction. Diagnosis is made based on history and clinical markers. This situation may pose a risk of re-infarction.
Anterior MI's refer to the sight of injury. Looking at specific leads can narrow the location further. Anterior MI's are identified in leads V2- V4. Anterior septal MI's are seen in leads V1 – V2 because of septal branch occlusions. When the **LAD** (left anterior descending artery) or Diagonal is involved, changes will be seen in leads V3 – V4. The changes that are seen include ST-segment elevation, deep Q-waves, & loss of **R-wave progression** (V1 should show small R-waves, which then become larger through precordial leads and largest in V4 before becoming small in V6 again). Anterior MI's can lead to heart failure, shock, atrial & ventricular

dysrhythmias, **Mobitz II** (intermittent, non-conducted P-waves without progressive prolongation of PR-interval), complete heart block (CHB), bundle branch block (BBB), ventricular septal defect (VSD), rupture, or aneurysm.



Pacemaker

Wandering atrial pacemaker (WAP), like multifocal atrial tachycardia, is caused by frequent and unpredictable beats in the atria that are discharged from different areas (foci) within the atrium. It is similar to MAT, except the heart rate is usually slower (less than 100 bpm).
EKG characteristics of Wandering Atrial Pacemaker:

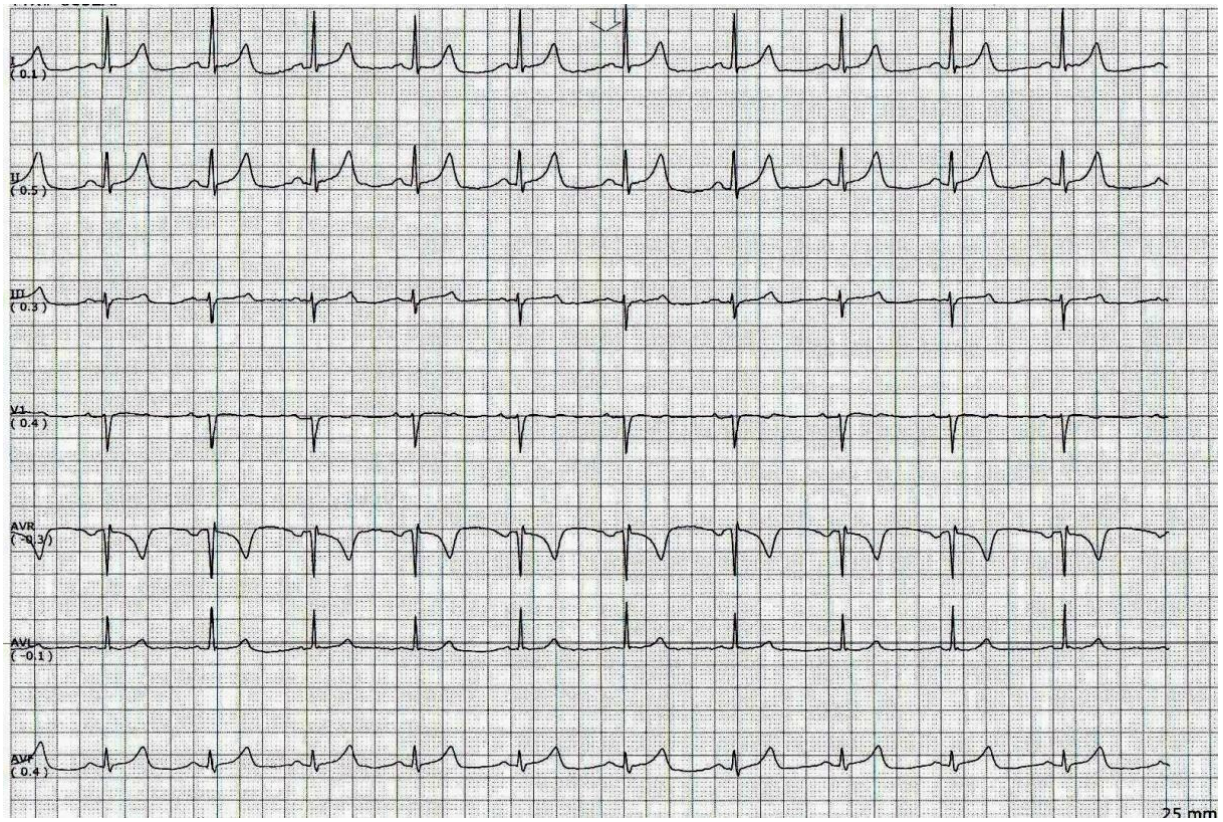
- An irregular rhythm is caused by impulses being triggered from different sites.
- Normal heart rate: 60 – 100 bpm.
- At least three different types of P waves
- P-QRS ratio: 1:1.
- Variations in the PR intervals.
- Normal QRS complex forms: 0.06 – 0.10 seconds.

Like MAT, the wandering atrial pacemaker is usually asymptomatic and doesn't usually necessitate treatment.

Torsade de Pointes

Torsade de Pointes or Polymorphic ventricular tachycardia looks the same a ventricular tachycardia. However, the amplitude of the QRS undulates. This is due to a rotation of the electrical axis or direction of electrical impulses.

Chapter 12. Exercises in ECG Interpretation

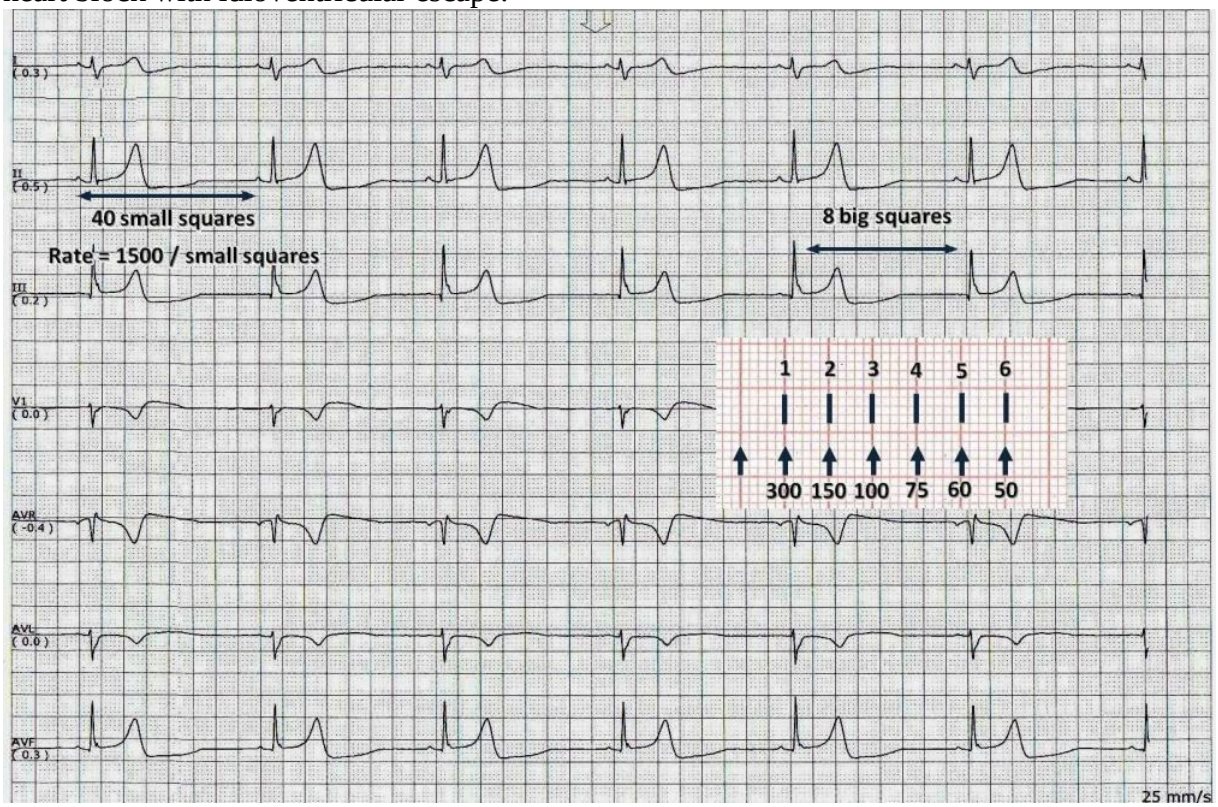


1. What is Normal Sinus Rhythm (NSR)?

Normal sinus rhythm (NSR) is an impulse that originates in the sinus node. It is recognized by the P wave morphology :

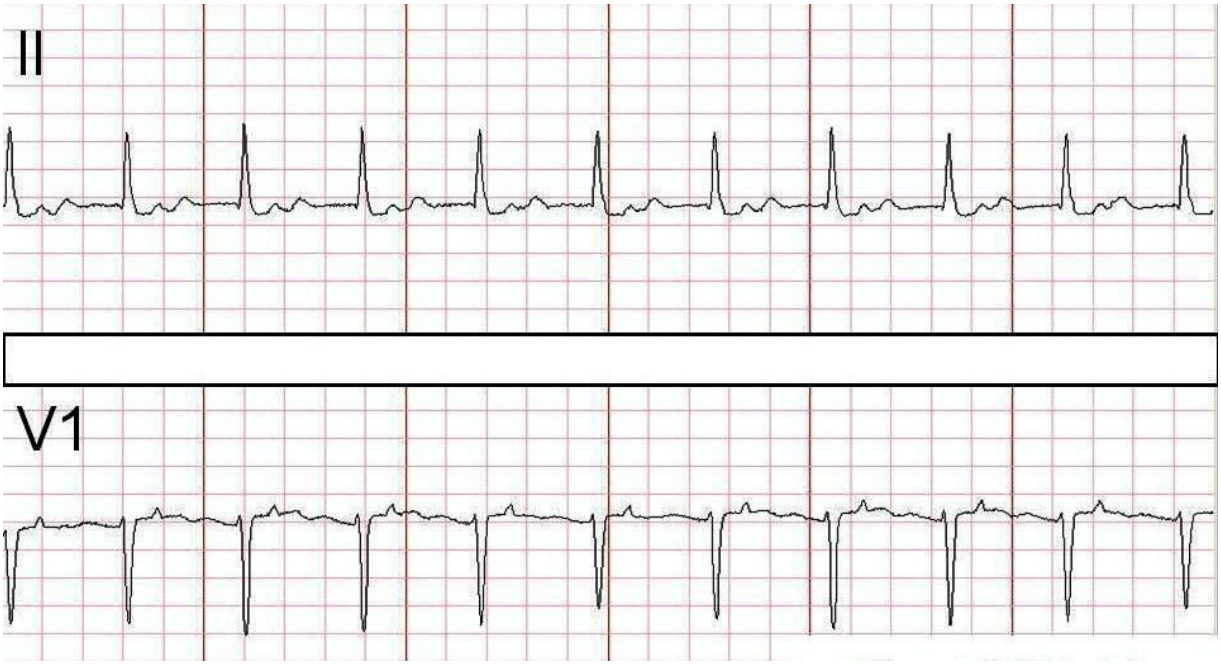
- Upright P in leads I, II, and aVF;
- inverted in aVR;
- P wave is variable in leads III and aVL
- P wave is upright in leads V4-V6
- Most often biphasic(positive-negative)in leads V1 and V2
- Minor variations in P wave morphology related to the respiratory cycle

PR interval (PRI) exceeds 120 ms or 0.12 s and can vary slightly with rate.
The rate can be between 60-100 beats/min. Most cardiologists agree that the operational limits for NSR range from 50-90 beats/min.
Rates lower than 60 beats/min are bradycardia, and rates higher than 100 beats/min are tachycardia.
During some AV blocks, the P waves are not followed by a QRS. You still interpret it as sinus rhythm (bradycardia or tachycardia). So, you will see interpretations like sinus rhythm, complete heart block with idioventricular escape.

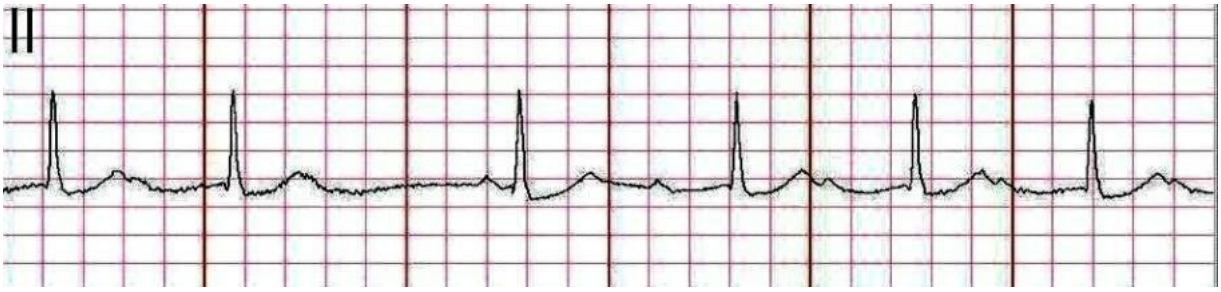


2. Computing the rate: the Big square and small square method

The quickest method to estimate the rate is to use the BIG SQUARE METHOD (shown in the image). The R to R is 8 big squares (less than 50). Another way is to use the SMALL SQUARE METHOD (Rate = 1500/ #small squares or, in this case, 1500/40 = 37 beats/min). P waves are upright in I, II, and aVF and inverted in aVR. Then this is sinus bradycardia.



3. What is the interpretation?



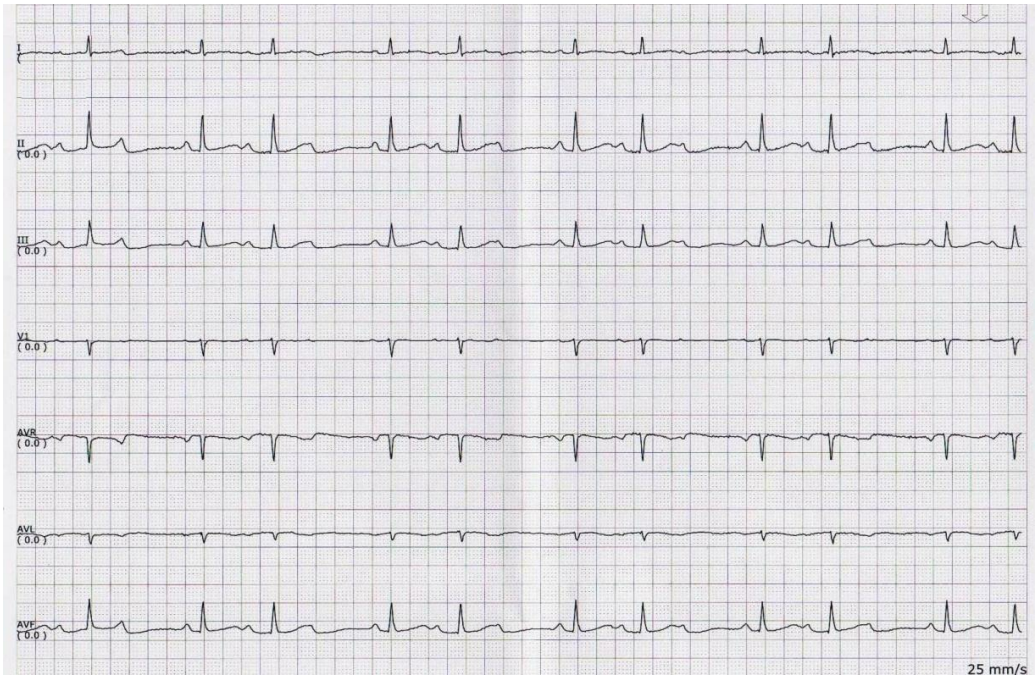
Middle of the Wenckebach
There are 3 possible interpretations for this strip.

1. Sinus tachycardia (ST) with long PRI (first degree AV block). The atrial and ventricular rate is about 100 bpm with a prolonged PR interval (PRI) of 0.44 sec. It is possible to see P waves between a QRS and T wave (as in this case).
2. Sinus tachycardia with accelerated junctional rhythm (creating AV dissociation). The ventricles can be captured by an impulse coming from the AV junction and not the sinoatrial node (SAN). The atrium and the ventricle are beating independently of each other or are DISSOCIATED. The inverted P from the junctional beat cannot be seen because the impulse from the junction going up to the atrium is blocked.
3. **Middle of the Wenckebach cycle**

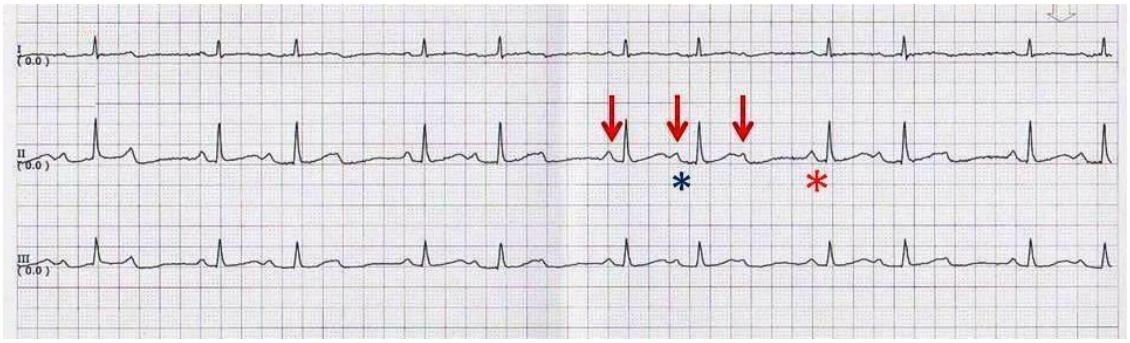
The strip below is from the same patient showing the end and beginning of the Wenckebach cycle. ECG # 3 is the middle part of this whole cycle. Remember that the heart is continuously beating. The ECG is like a photograph or a snapshot of cardiac

electrical activity.

You may be correct if the strip was interpreted as the above two, but in this clinical scenario, ECG # 3 is part of the Wenckebach. So, there can be more than one possible interpretation of a strip.



4. What is the ECG interpretation?

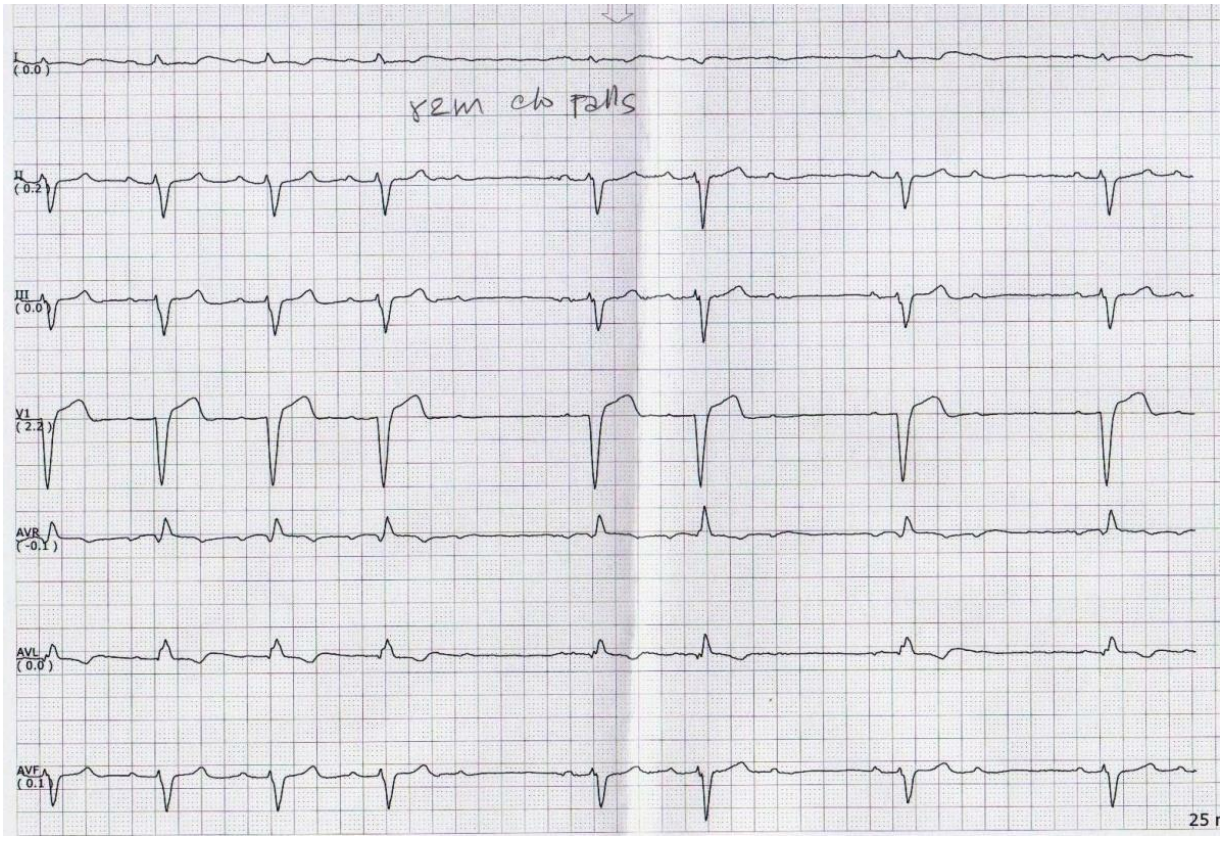


Second Degree AV Block Type I or Mobitz I (Wenckebach)

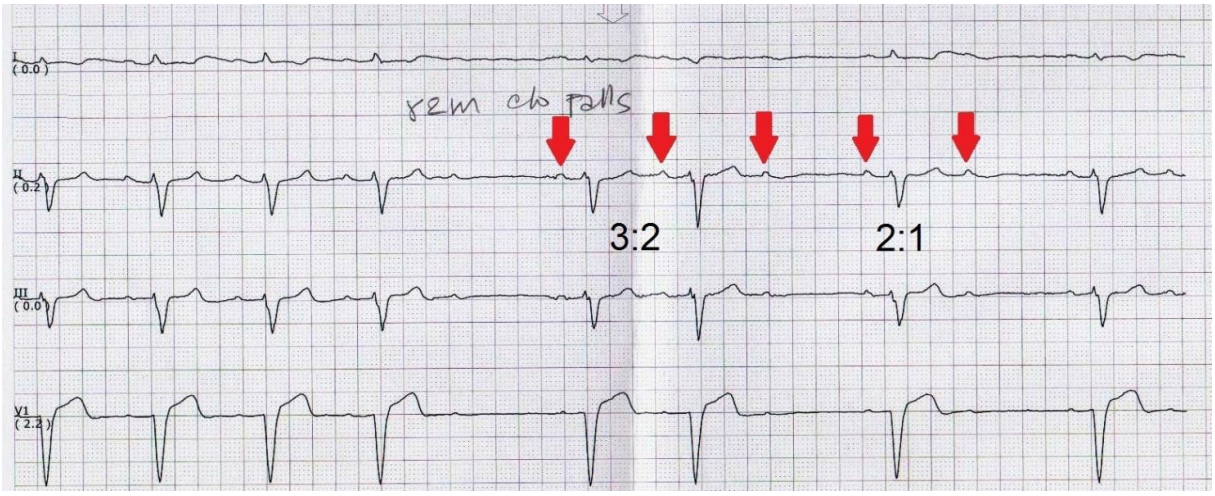
This is a sinus rhythm with 3 P waves (red arrows) for every 2 QRS (3:2). There is a prolongation of the second PRI before the non-conducted P wave. This is a *typical Wenckebach* pattern. A *quick way* to spot Wenckebach during sinus rhythm is to compare the PRI of the last conducted beat (blue asterisk), which is 0.24 sec or 6 small squares, with the PRI of the first conducted beat (red asterisk), which is 0.20 sec or 5 small squares. *The PRI of the first conducted beat is shorter compared to the PRI of the last conducted beat*. The obvious *prolongation of the PRI in the second conducted beat* is another quick way.

As you master the art and the more strips you see, “group-beating” of the QRS is (in the words of

Dr. Marriott) “footprints of a Wenckebach”. So, when you see “group-beating,” suspect a Wenckebach.

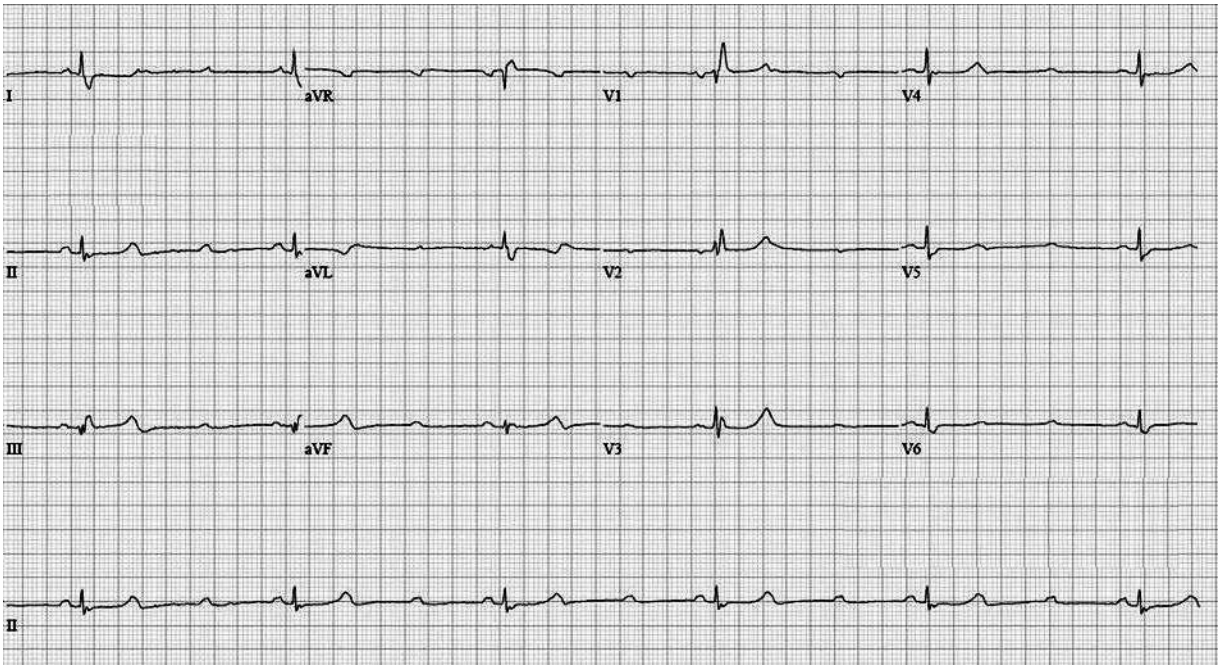


5. What is the ECG interpretation?

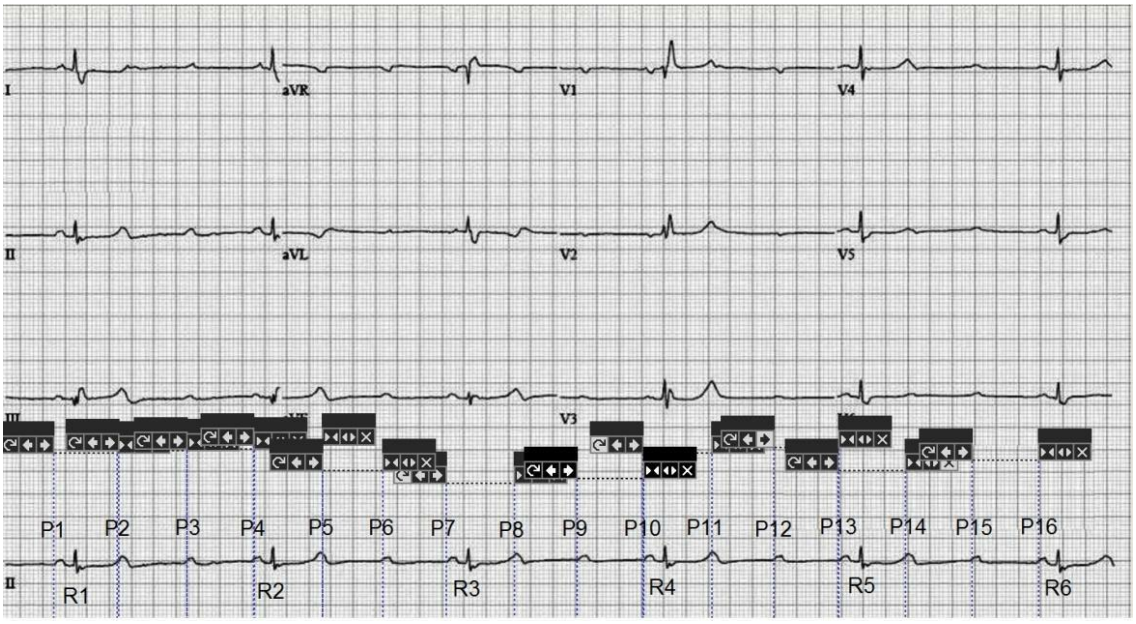


Second degree AV block type II or Mobitz II

The strip showed dropped beats with 3:2 and 2:1 AV conduction. The PR interval before the dropped beat did not increase (but prolonged at 0.24 sec or 240 ms). Permanent pacemaker implantation was done. You do not see this all the time. This is rare.



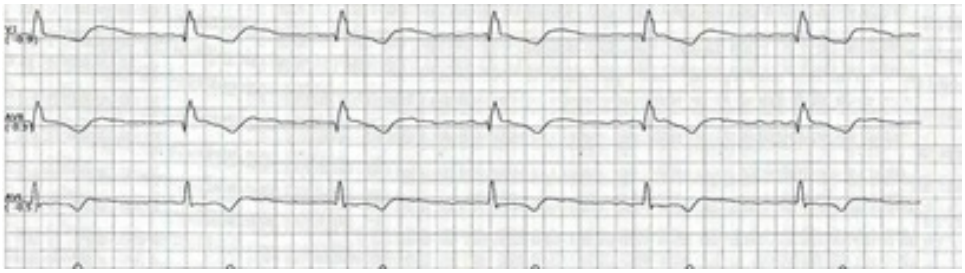
6. What kind of heart block?



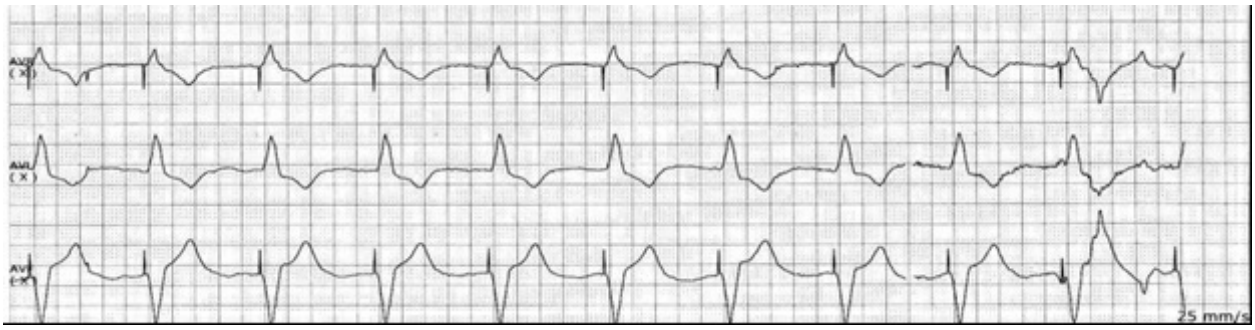
Advanced heart block or high-grade AV block

When **2 or more P waves are non-conducted in a row**, the term high-grade or advanced second-degree AV block is applied.

Reference: Goldberger A. 2013. Goldberger's Clinical Electrocardiography: A Simplified Approach. 8Ed Ph Elsevier

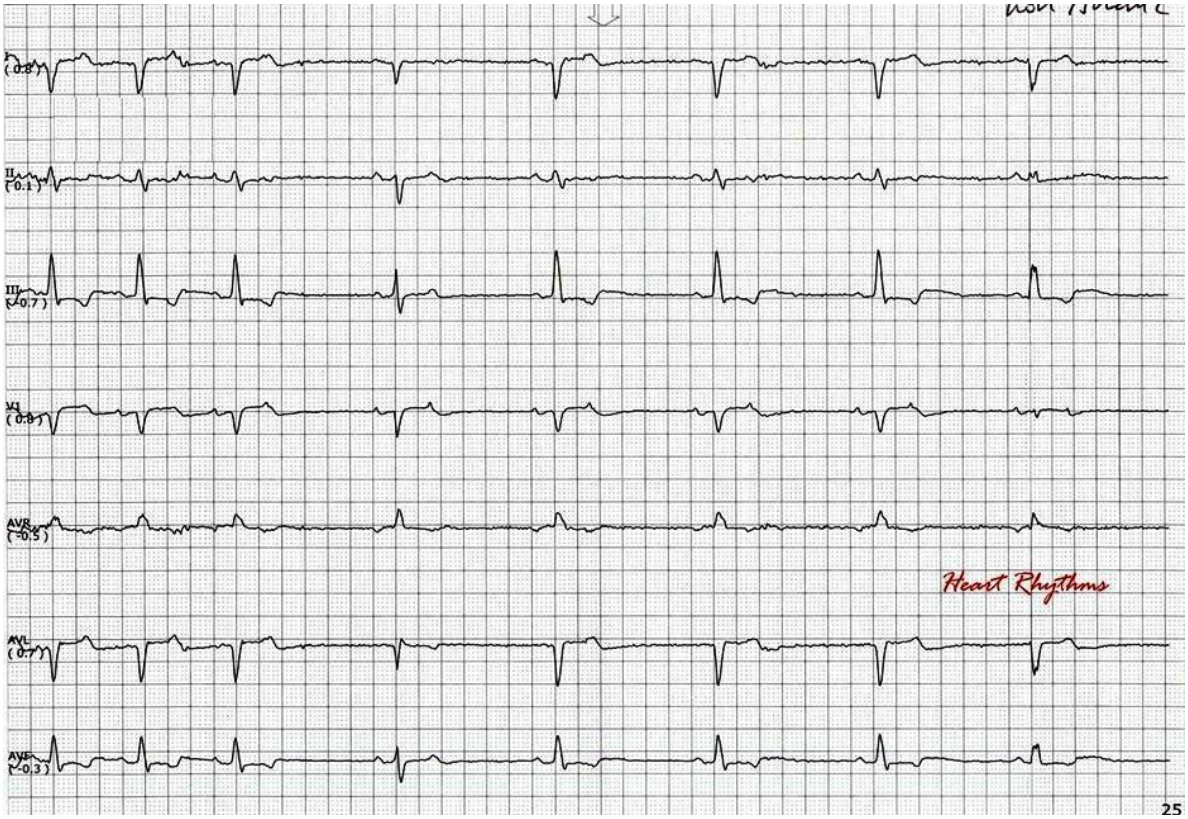


7. A patient complaining of dizziness. What is the rhythm?

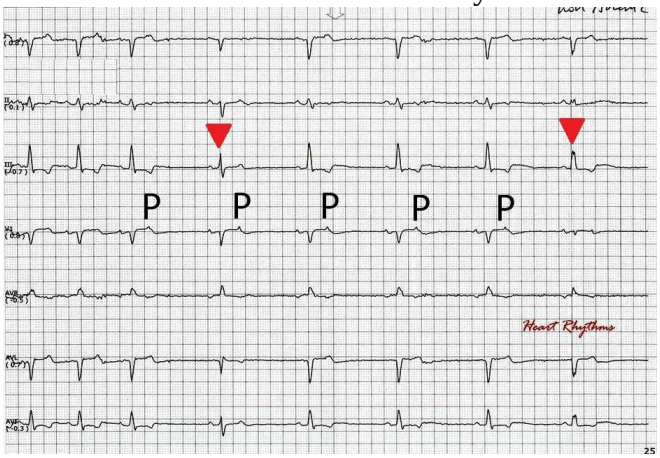


Atrial fibrillation with complete heart block

The ECG shows regular wide QRS rhythm (RBBB morphology) at ~30 bpm with no discernible P waves. There are no flutter waves to explain the regular ventricular response. This ventricular rate is too slow for a junctional rhythm (which may conduct with RBBB morphology). The rhythm that can explain this is atrial fibrillation with complete heart block with idioventricular rhythm. A pacemaker was eventually placed.

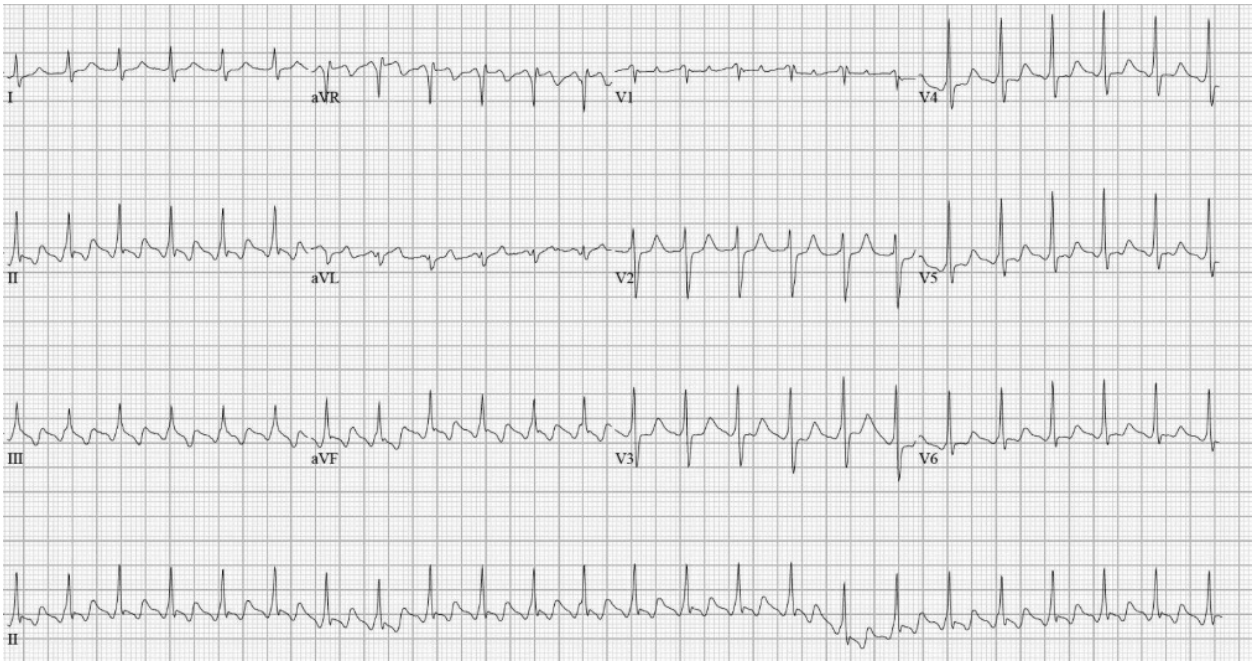


8. What is the cause of the sudden bradycardia?

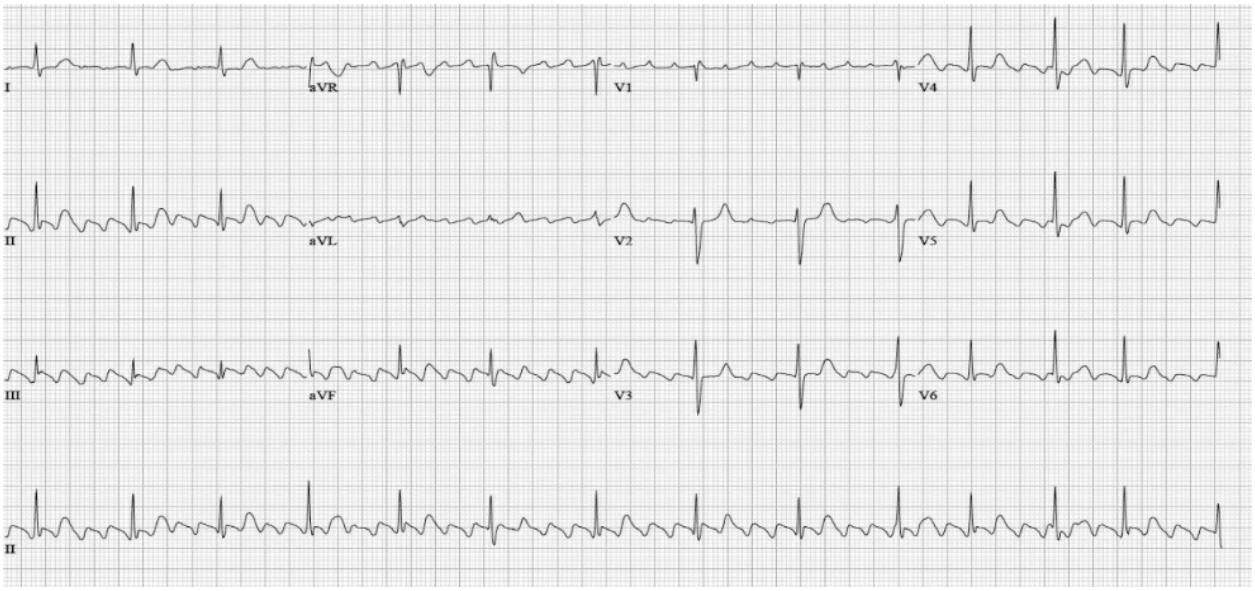


Non-conducted premature atrial beat in bigeminy

Use all leads to look for the "missing". The best candidate is V lead. The T waves in QRS # 1 and 2 are not as pointed compared to the next T waves. So, these are P waves "sitting" on the T waves. These P waves are too early for the sinus cycle. So, the cause of the bradycardia is **non-conducted PAB in bigeminy**. It is also noticeable that some of the QRS (red arrowhead) are conducted with aberration.

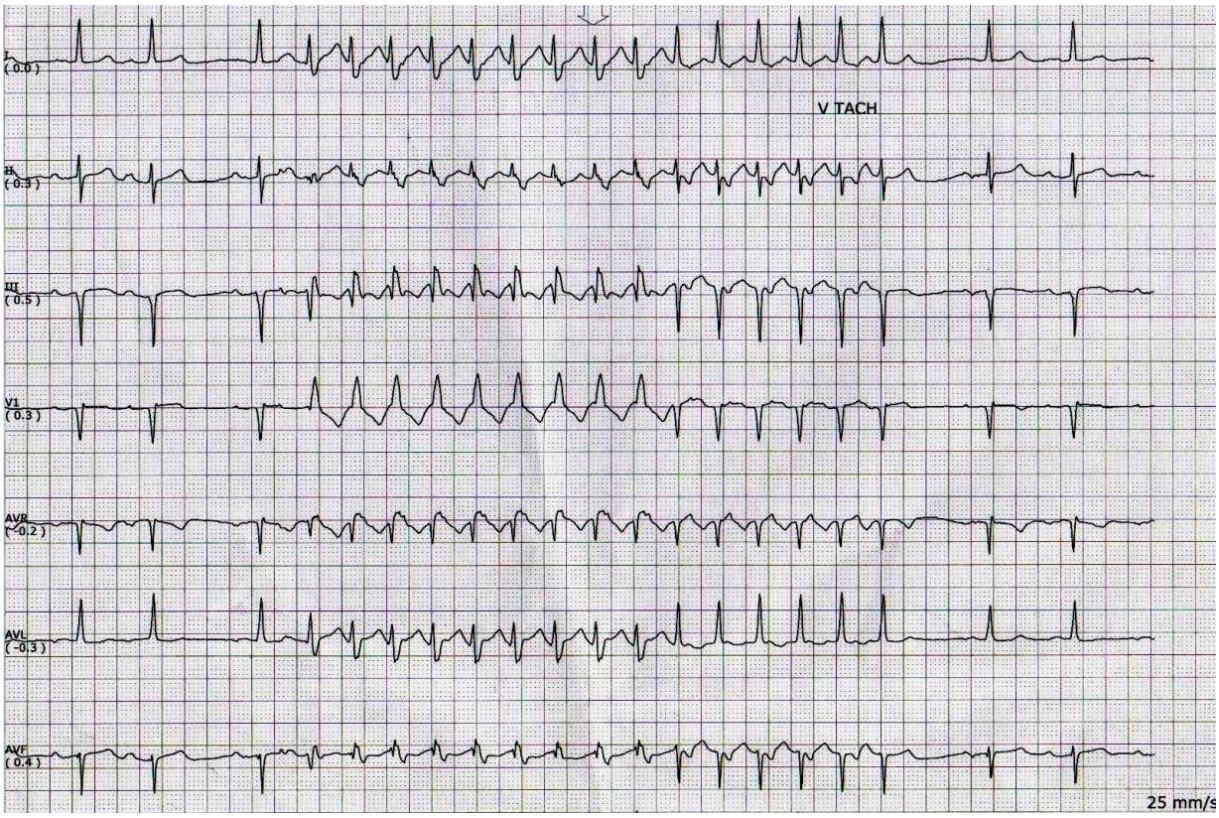


9. A patient is admitted for syncope. The machine read as acute MI. Do you agree with the machine?

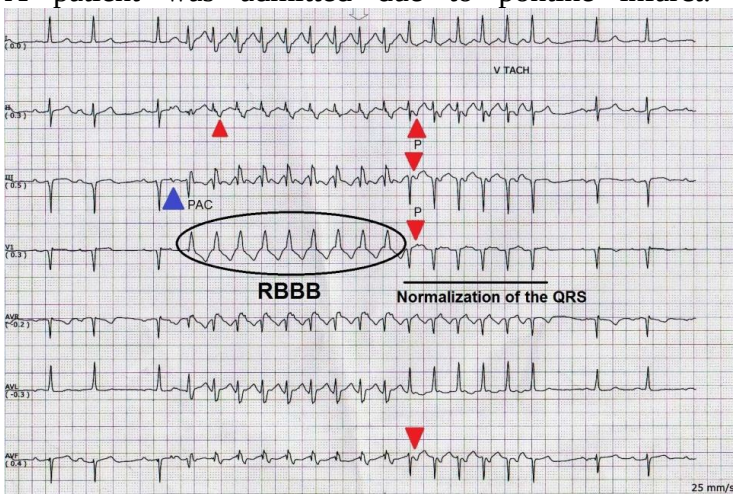


Atrial flutter with 2:1 AV conduction

This is a regular narrow complex tachycardia at a rate of about 150 bpm. ECG machines often misinterpret these tracing because of the flutter waves distorting ST segments. This is actually atrial flutter with 2:1 AV conduction simulating an inferior wall STEMI. The 12L as slower ventricular response clearly shows those flutter waves.



10. A patient was admitted due to pontine infarct. What is this rhythm?



Paroxysmal supraventricular tachycardia (SVT) with aberrancy with spontaneous normalization

The *middle of the strip* shows a regular tachycardia that started with a PAC (blue arrowhead). The next 9 beats had a **right bundle branch block or RBBB configuration** (circled black) and later the **QRS width normalized (**black line). There are (inverted) P waves (red arrowhead) right after the QRS in II, III, and aVF, as well as in the V lead. This is paroxysmal supraventricular tachycardia (SVT) with aberrancy with spontaneous normalization. This type of SVT can be described as a **short RP tachycardia**.

Conclusion

The medical field is as vast and deep, just like an ocean. There are millions of clinical facts, and figures and NO body can remember all of them. Similarly, in one's clinical career, one will meet several patients, but one can't save them all.

But just by acquiring enough and precise medical knowledge, one can make a significant difference in someone's life. Learning how to interpret ECG is one of those lifesaving skills.

ECG, since its time of invention, has made a substantial change in the field of medicine. It is now taken as one of the baseline investigations for the diagnosis of conditions related to the heart. It is non-invasive and easily accessible. It is one of the essential tests for evaluating the abnormalities associated with cardiac rhythm. Timely detection of myocardial ischemia and myocardial infarction is only made possible due to ECG. Defects in the conduction system, preexcitation, long QT syndromes, atrial anomalies, ventricular hypertrophy, pericarditis are few other disorders that can be diagnosed by ECG.

As you have seen, without a regular rate and rhythm, the heart will not be able to efficiently pump and circulate oxygenated blood and other nutrients to the tissues and organs of the body. Hopefully, the critical nature of this topic has been impressed the reader.

A comprehensive understanding is crucial, and we hope that you will continue to develop your understanding of electrophysiology by viewing and analyzing as many strips as possible. We encourage you to make it a point to seek out real-life examples within your clinical setting. Repetition is the key to successful understanding. Gather all information at your disposal and trust yourself when you are interpreting an EKG.

Putting It All Together

Using a systematic approach to interpreting EKGs is essential so that vital characteristics are not overlooked. Features that require analysis include heart rate, rhythm, intervals, conduction defects, chamber enlargement, and ST & T-wave changes. To conclude this book below is a step-by-step guide regarding how to evaluate each of these features.

Components

Heart rate can be calculated easily if the rhythm is regular by counting the number of 1 mm squares between two heartbeats (RR-interval) and dividing this number into 3000 if the paper speed is 50 mm/s (3000 = 1 minute b/c 60 sec. x 50 = 3000), or into 1500 if the paper speed is 25 mm/s (the common standard). If the heart rate is irregular, the average over a period of time must be determined. It is important to note that 30 large squares or 150 mm represent 3 seconds at 50 mm/s or 6 seconds at 25 mm/s. The heart rate can be evaluated by counting the number of QRS complexes over 30 large squares and multiplying by 20 if at 50 mm/s or 10 if at 25 mm/s.

Conventionally, a normal heart rate is 60 – 100 bpm. Clinical context is important because a well-trained athlete, for example, may have a heart rate of 85 bpm, which is considered tachycardia.

Rhythm refers to the pattern that the heartbeats and the electrical sequence displayed on EKG.

Approach

1. Trust your first impression.

Examine the EKG briefly and see what jumps out. Oftentimes, pacer spikes, peak T-wave, or other prominent findings can be very telling. Retain this first impression before methodically narrowing your search. Keep it in mind moving forward.

2. Explore it step-by-step and in detail.

Consider each beat and determine if and how they look different from one another. Use the normal beats and their segments, intervals, etc., as a comparison. Do you see PVCs, bundle branch blocks, or anything abnormal?

3. Rate?

Tachy/Brady, irregular/regular?

4. Rhythm?

Irregular/regular, P-waves present and uniform, P-to-QRS ratio, complexes, intervals, wide/narrow, depressed, peaked, notched?

5. Hypertrophy?

LAH, RAH, LVH, RVH, strain patterns?

6. Ischemia or Infarct?

T-wave & ST-segment abnormalities, Q-waves?

7. List.

Record rate, rhythm, hypertrophy, intervals deviations, blocks, and ST & T-wave deviations.

8. Correlate.

Are there any physical findings or otherwise that supports my impression?

Lab Values Interpretation

A complete step-by-step guide to the interpretation of laboratory values plus everything you need to know about laboratory values and their importance in diagnosing diseases

Introduction

The following chapters in this book will discuss everything you need to know about how to interpret different lab values. This book will help you in understanding some of the standard tests which are conducted and how to interpret the lab values gotten from such tests.

The skill of being able to interpret laboratory investigations and understand the science behind them is crucial in the medical field. In fact, approximately 65-75% of decision-making in medicine is done based on the results of laboratory tests. Laboratory values essentially provide data in an objective form that relates to a patient's health; hence, proper interpretation of such values is instrumental in coming up with the correct diagnosis. Laboratory values can aid in the early diagnosis of diseases that have not yet had clinical manifestations, thereby leading to the more effective management of such conditions.

Needless to say, insufficient understanding of laboratory tests and the subsequent lab values gotten from such tests in a clinical setting can lead to a misinterpretation of the results, and this can jeopardize the safety of a patient.

All the chapters in this book are essential and will take you through a step-by-step journey that will enable you to measure your patients' health objectively.

Let us get started on the journey to understanding and correctly interpreting laboratory values!

Chapter 1: Introduction to Lab Values

Laboratory tests are procedures wherein a sample of blood, urine, other bodily fluid, or tissue are checked in order to see if the resulting lab values fall within the normal range. Lab values, often abbreviated to "lab values," are used to assess a patient's overall health and well-being. There are many factors that can affect a patient's results and lab values, the most common ones include age, race, gender, type of medications taken, and the presence of any underlying conditions. Usually, before a test is carried out, doctors will advise the patient to skip drinking, eating, and taking medication several hours before the test as any of the aforementioned actions can affect the patient's result as well as the lab values.

Lab values can be used to diagnose an individual's overall health as well as specific aspects of an individual's health. In order to diagnose an individual's health, physicians will compare current lab values with previous results to determine any changes in health as well as the effectiveness of any treatment the individual might be currently undergoing.

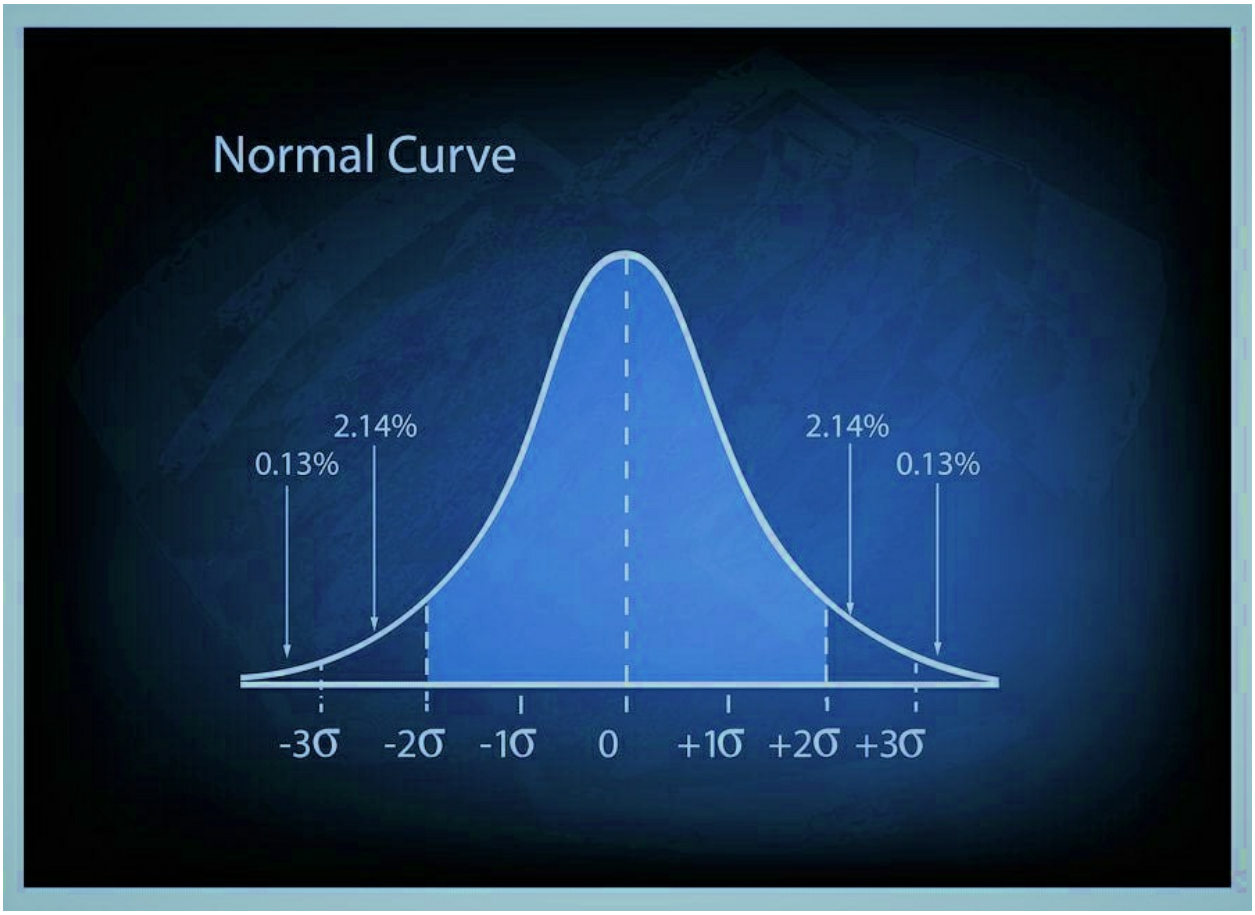
Needless to say, lab values are derived from lab tests. These tests can be used in many different ways. For instance, a lab test can be used to diagnose or rule out a specific disease or condition, and an example of this is an HPV test. An HPV test can indicate whether an individual has an HPV infection or not. Lab tests can also be used to screen for disease. A screening test can be used to determine if an individual is at a higher risk of getting a specific disease. It can also be used to determine if an individual has a disease, even if such an individual is not showing any symptoms. Additionally, a lab test can be used to monitor disease and/or treatment. If an individual has already been diagnosed with a disease, lab tests can show if such an individual's condition is getting better or worse. It can also show if the treatment of such disease is working or not. Finally, as mentioned earlier, lab tests can be used to check an individual's overall health as lab tests are often included in a routine checkup. A medical practitioner may order tests of various organs and systems to see if there have been changes in an individual's health over time. Lab tests can help medical practitioners find health problems before symptoms appear, while lab values gotten from the tests can be used to determine if the results from the tests are within normal or abnormal levels.

What Are Normal Lab Values?

"Normal lab values" refer to a range of values that 95% of a healthy population falls into. However, it should be noted that there are some exceptions to this. For instance, when checking for troponins – which are markers of heart damage – 99% of the healthy population have values that fall within the normal range.

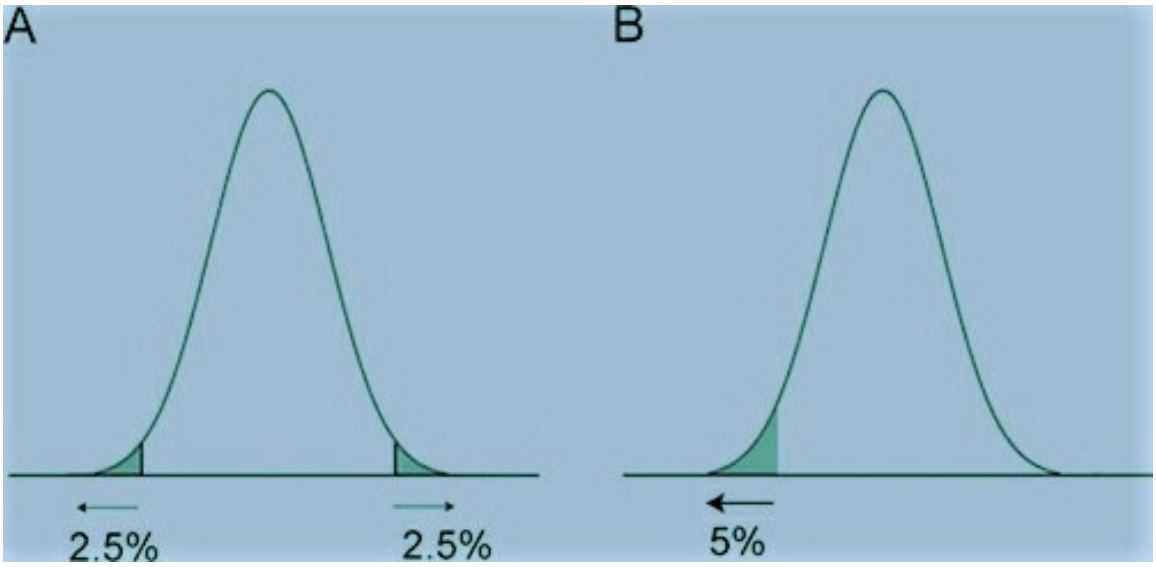
Normal intervals are commonly referred to as reference intervals by laboratories and healthcare professionals. Doctors use these ranges to interpret their patients' lab test results, help make a diagnosis, or decide on treatment.

However, in the context of lab test results, "normal" does not mean typical, usual, or ordinary. Instead, "normal" refers to how these values arrange on a graph and form a range. The word "normal" here means a "normal distribution," or a set of laboratory values. Thus, when we graph this, it looks like the symmetrical, bell-shaped curve shown in the image below.



In a normal distribution, the average value lies in the center. Hence, half of the population will have values that lie on the left side of this average while the other half will have values that lie on the right side; and this accounts for 95% of the population. Not surprisingly, in real life, the set of lab values taken from a population won't fit this bell shape perfectly; Instead, the similarity is close enough to make it useful in creating reference intervals for most tests.

Once 95% of the values are considered, the remaining ones fall outside the reference interval. The 2.5% of either end of the curve above indicates "outside" the reference interval. Any lab value that falls in these areas is flagged as abnormal and will be brought to the attention of a healthcare provider. However, in cases where "low" marker values are of interest to clinicians and indicate a disease or disorder, the reference interval will be one-sided on the left with a 5% tail as the abnormal range (instead of the 2.5% tails on either end). This is illustrated in the image below.



An example is the sperm concentration test, where only low values are likely to worry doctors. In other cases, only "high" values may indicate health problems, and the abnormal range will be the 5% tail on the right.

How Reference Ranges Are Created

Reference range, which is also commonly referred to as reference interval by labs and doctors, can be created in different ways. However, the benchmark is to conduct a reference interval study.

Reference Interval Studies

Basically, a reference interval study analyzes a large number of test results from healthy individuals, and these studies are often performed according to established international clinical and laboratory guidelines.

The first step for the reference interval study is to identify a healthy reference population from which to sample. The minimum number of people needed for the study is 120, according to the new guidelines. Absence of disease is the main difference between this population and the patients to whom the test will be applied.Some tests must have more than one reference interval because of factors that may affect the results. For example, women and men have separate ranges for total testosterone levels. The main factors that determine the need for multiple reference intervals are age, sex, reproductive status (puberty, stage of pregnancy, and menstrual cycle), race (e.g., prostate-specific antigen in African Americans), and time of day at which a sample is collected (e.g., random or early morning urine sample).

Reference interval tests need to be performed exactly the same way in the lab in order to generate accurate results. For example, the time of day for sample collection, a person's fasting status , the analysis of the sample (such as the amount of time before the sample is analyzed), - all must be the same. Target populations are selected from volunteer blood donors, door-to-door contacts, medical students, and hospital patients. Potential participants are asked to fill out questionnaires about their health status in order to exclude individuals based on specific criteria such as physical activity levels, medical history, medication use, and the presence of certain diseases. Samples are

then taken and the most extreme test results are removed.
The final step in conducting reference interval studies is to analyze the laboratory results and identify the upper and lower limits into which 95% of the values fall.

A Posteriori Studies

A posteriori studies are an alternative to reference interval studies and involve searching existing patient data – which is collected by labs and hospitals and stored in electronic databases – and analyzing it. This type of analysis is referred to as "a posteriori" because it means that the research is done after ("post") collecting the information. Because the data are easily accessible, these studies are inexpensive, less time-consuming, and can include a large number of patient samples. It should be considered that some samples may not be from healthy subjects, especially when it comes to samples from hospitalized patients. However, despite this potential drawback, multiple a posteriori studies have found relevant and meaningful ranges for evaluating test results.

Decision Limits

A decision limit is a "cutoff" point where values above or below are linked to an increased risk of developing certain diseases. Their purpose is to indicate when intervention is needed in order to then prevent the disease. Some markers are assigned a decision limit (or multiple decision limits) that are (are) better than reference ranges in making diagnosis and treatment decisions. Sometimes, decision limits may also be based on the clinical experience of clinicians.

For example, one test that has multiple decision limits is total cholesterol. The upper limits for total cholesterol levels accepted by laboratories and physicians are 200 mg/dL and 240 mg/dL. These limits were established by an expert panel for the National Cholesterol Education Program (NCEP), a program administered by the National Institutes of Health. Levels between 200 mg/dL and 240 mg/dL are associated with a moderate risk of heart disease, while levels above 240 mg/dL are associated with a high risk. These limits tell physicians about which treatment options to use, such as dietary interventions, lifestyle, and/or prescribing statins and other cholesterol-lowering drugs. Other examples of tests with decision limits include blood glucose and HbA1c (a measure of long-term glucose levels).

Different Labs, Different Reference Ranges

There is no universal reference range for most lab tests; hence, ranges tend to vary from lab to lab. This means that it is quite possible to get a typical result from one lab and an abnormal result for the same test from another lab, and vice versa.
Theoretically, reference ranges should be established for each marker by every lab; however, in reality, only a few labs carry out their own reference interval studies. This is because recruiting a healthy reference group and getting their informed consent is expensive and time-intensive. Therefore, most labs opt to use the reference ranges provided by the test manufacturers. This is preferable because the lab only needs to use 20 sample tests to verify that the manufacturer’s

range is accurate. Even at that, some labs may skip this step.
Laboratories face many challenges when conducting reference interval studies; challenges such as creating reference intervals for different subpopulations, tests that require multiple measurements, and rare sample types (e.g., cerebrospinal fluid). To circumvent these challenges, laboratories sometimes use intervals established by previously published reference interval studies or even use intervals established by other laboratories.

Advantages of Reference Ranges

- Reference intervals are useful because they provide fixed values of healthy populations with which health care providers can compare patients' laboratory results. This allows them to make treatment decisions.
- Reference ranges are also appealing to patients (even if they may not know precisely what they mean) because they can see where their results fall in relation to upper and lower limits.

Drawbacks of Reference Ranges

- The reference intervals do not take into account the results of numerous population-based research. This research may reveal different limits for increased risk of mortality and disease. Decision limits are sometimes better for this very reason.
- Reference ranges do not take into account the uniqueness of daily and annual variations in each person's biology, genetics, and environment. Instead, they are arbitrary "cutoffs" based on how laboratory values are distributed in a "healthy" population, which is difficult to define. A reference population may still contain people with an undiagnosed disease or condition that affects their laboratory results.

Outside-the-Range Values

Just because an individual’s lab value falls outside the normal range does not necessarily mean that such an individual has a disease or a disorder. In fact, and by definition of typical range values, 5% of healthy individuals will have levels outside of the normal range.
Conversely, a typical lab value does not guarantee the absence of a disease or disease process. Hence, it is crucial that an individual’s healthcare provider examines their lab results in relation to one another. They should also take into account an individual’s medical and family history as well as any previous test results in order to identify trends.
It’s also important that a lab result is interpreted in light of the reason for requesting the test, such as a routine health check, managing a disease, or making sense of an individual’s overall symptoms. For example, a healthcare provider may interpret the same total cholesterol value of 241 mg/dL differently for two patients if one has no history of heart disease and the other previously suffered a heart attack and is on statins. The healthcare provider may also be inclined to retest the patient with no past history of heart disease while continuing or increasing the current statin dosage for the patient with heart disease.
Another important consideration is how far outside the normal range an individual’s lab test

result is. For example, sodium concentrations in the blood are kept in a tight range. Lab results that are even slightly too high or too low can be dangerous even in the short-term.

For most tests, if an individual’s result is slightly outside of the normal range or the abnormal result does not match the rest of the individual’s results, the health care provider may order additional testing or repeat the same test in order to confirm it. Factors that can cause abnormal values, even with the absence of a disease or disorder, include errors in sample processing and analysis, poor patient compliance in pre-test preparation (e.g., not fasting or discontinuing prescription medication), and random fluctuations in the patient's biology.

Normal Lab Values vs. Optimal Values

A normal reference range does not always give an idea of the optimal range for a laboratory test. For several reasons. The most obvious reason is that by its very design and nature, a reference interval is not intended to capture the optimal range. It is simply an interval based on samples from a predefined population.

Another reason that reference intervals do not provide any information about optimal values is that they rarely take into account research on the risk of developing certain diseases.

Finally, the reference population may not have optimal levels. If the reference population is not sufficiently healthy, this is reflected in the reference interval.

Chapter 2: Basic Chemistry Panel

The basic chemistry panel – also known as the basic metabolic panel – is a blood test that measures the sugar (glucose) level, electrolyte and fluid balance, and kidney function of an individual. This blood test consists of a set of seven biochemical tests and is one of the most common lab tests ordered by healthcare providers.

Outside the United States, blood tests consisting of most of the same biochemical tests are called urea and electrolytes (U&E or "Us and Es"), or electrolytes, urea and creatinine (UEC or EUC or CUE), and are often referred to as "renal function tests" because they also include an estimate of the calculated glomerular filtration rate. The basic chemistry panel provides key information regarding kidney function, fluid and electrolyte status, blood sugar levels, and response to various medications and other medical therapies. For instance, if an individual takes any medicines, such as diuretics for high blood pressure, a healthcare practitioner may order a basic chemistry panel to see if the drugs are affecting the individual's kidneys or electrolytes. A healthcare practitioner may also order this panel as part of a regular health examination or to help diagnose a medical condition in an individual. The panel is also frequently employed as a screening tool during a physical exam.

It is important to note that the basic chemistry panel is a simpler version of the comprehensive metabolic panel (CMP), which includes tests for liver function.

As mentioned earlier, the basic chemistry panel involves seven tests, and these seven tests are often referred to by medical professionals in the United States as the "CHEM-7" or "SMA-7" (Sequential Multiple Analysis-7). The seven tests under the basic chemistry panel are:

- Calcium
- Magnesium
- Phosphorus
- Potassium
- Sodium
- Chloride
- Serum proteins

These levels, taken as a set, can be quickly run to indicate several common acute conditions that require specific and immediate medical treatment, such as dehydration/hypovolemia, water intoxication (which may present with symptoms similar to dehydration but require the opposite treatment), diabetic shock (either ketoacidosis, hyperglycemia, or hypoglycemia), renal or hepatic failure, congestive heart failure, overdoses of various substances or adverse reactions, and others. Therefore, Chem-7 is a vital tool when attempting to stabilize a patient.

Calcium is often considered as part of the basic metabolic panel, though by definition, it is not part of the CHEM-7. Thus, a basic metabolic panel including calcium is sometimes colloquially referred to as a "CHEM-8". In countries that do not use the CHEM-7 panel, a UEC typically does not include chloride or bicarbonate as standard components, although it very often includes an estimate of glomerular filtration rate (eGFR), and in several laboratories, glucose is also not included but is available as a separate test.

Calcium (Ca)

Test Overview

A blood calcium test checks the level of calcium in the body that is not stored in the bones. Calcium is the most common mineral and also one of the most important minerals in the body. The body needs it to build and repair bones and teeth, but also to help nerves work, help blood clot, make muscles tighten, and help the heart work. Almost all of the body's calcium is stored primarily in the bones.

Typically, the level of calcium in the blood is carefully controlled in the body. Thus, when calcium levels in the blood get low (hypocalcemia), the bones release calcium into the blood to bring it back to a good level. When calcium levels in the blood get high (hypercalcemia), the extra calcium is stored in the bones or passed out of the body in urine and stool.

Usually, most people who have high or low levels of calcium do not have any symptoms. Hence, calcium levels need to be very high or very low to cause symptoms.

Why the Test Is Done

A blood calcium test may be done:

- As part of a routine blood test.
- To check for problems with the parathyroid glands or kidneys, bone problems, and some types of cancer or inflammation of the pancreas (pancreatitis).
- After a kidney transplant.
- To find a reason for an abnormal electrocardiogram (EKG) test.
- To see if an individual's symptoms may be caused by a very low calcium level in the blood. Such symptoms may include muscle cramps, twitching, and spasms, tingling in the fingers and around the mouth.
- To see if an individual's symptoms may be caused by a very high calcium level in the blood. Such symptoms may include weakness, lack of desire to eat, lack of energy, nausea, and vomiting, urinating a lot, constipation, and belly or bone pain.How the Test Is Done

Calcium testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Total calcium	
Adults:	8.8–10.4 milligrams per deciliter (mg/dL) or 2.2–2.6 millimoles per liter (mmol/L)
Children:	6.7–10.7 milligrams per deciliter (mg/dL) or 1.90–2.75 millimoles per liter (mmol/L)

Ionized calcium	
Adults:	4.65–5.28 mg/dL or 1.16–1.32

	mmol/L
Children:	4.80–5.52 mg/dL or 1.20–1.38 mmol/L

An ionized calcium test checks the amount of calcium that is not attached to the protein in the blood. The level of ionized calcium in the blood is not affected by the amount of protein in the blood.

Abnormal Result

Abnormal results occur when extremely high calcium levels are discovered in the tested samples. This high calcium level may be caused by:

- Cancer, including cancer that has spread to the bones.
- Tuberculosis.
- Hyperparathyroidism.
- Being on bed rest for a long time after a broken bone.
- Paget's disease.

Abnormal results can also occur when extremely low calcium levels are discovered in the tested samples. This low calcium level may be caused by:

- A low level of the blood protein albumin (hypoalbuminemia).
- Hypoparathyroidism.
- High levels of phosphate in the blood, which can be caused by kidney failure, laxative use, and other things.
- Malnutrition is caused by diseases such as celiac disease, pancreatitis, and alcohol use disorder.
- Osteomalacia.
- Rickets.

Chloride (Cl)

Test Overview

A chloride test measures the level of chloride in an individual’s blood or urine. Chloride is one of the most important electrolytes in the blood. It helps keep the amount of fluid in and out of the body's cells in balance. It also helps maintain proper blood volume, body fluid pH, and blood pressure. Tests for sodium, bicarbonate, and potassium are usually done at the same time as a blood test for chloride.

Most of the chloride in the body comes from the consumption of salt (sodium chloride). Chloride is absorbed by the intestines when it digests food, while extra chloride is then eliminated from the body through urine.

Sometimes a test for chloride can be done on a sample of urine collected over a 24-hour period – it is called a 24-hour urine sample – to find out how much chloride is leaving an individual's body through their urine.
Chloride can also be measured in skin sweat to test for cystic fibrosis.

Why the Test Is Done

A test for chloride may be done to:

- Check an individual's chlorine level if such an individual is having symptoms such as muscle twitching or spasms, breathing problems, weakness, or confusion.
- Find out whether an individual has kidney or adrenal gland problems.
- Help find the cause for high blood pH. A condition known as metabolic alkalosis can be caused by a loss of acid from an individual's body (for instance, from a loss of electrolytes through prolonged vomiting or diarrhea). An individual may also have metabolic alkalosis if their body loses too much sodium or they consume too much baking soda (sodium bicarbonate).

How the Test Is Done

The test can be done in three ways depending on the reason(s) behind the test.

Blood Test

The health professional will take a sample of an individual's blood, and then the sample will be sent to the lab for analysis.

Urine Test

For the urine test, an individual will start collecting their urine in the morning.

- When such individuals first get up in the morning, they need to empty their bladder, but they do not need to save this urine. Instead, they need to write down the time they urinated to mark the beginning of their 24-hour collection period.
- For the next 24 hours, they need to collect all their urine. The medical practitioner or lab will usually provide such an individual with a large container that holds about 1 gal (4 L). The container has a small amount of preservative in it. The individual needs to urinate into a small, clean container and then pour the urine into the large container. The individual needs to make sure not to touch the inside of the container with their fingers.
- Then, the individual needs to keep the large container in the refrigerator for 24 hours.
- The individual needs to empty their bladder for the final time at or just before the end of the 24-hour period, then add this urine to the large container and record the time.
- It is important that the individual does not get toilet paper, pubic hair, stool (feces), menstrual blood, or other foreign matter in the urine sample.

Skin Sweat Test

The skin sweat test for chloride is primarily used to test for cystic fibrosis.

Results

Basically, a chloride test measures the level of chloride in an individual's blood, urine, and sometimes body sweat. Blood chloride levels are checked more often than urine chloride levels or sweat chloride levels, and results are usually available within 1 to 2 days.

Normal Result

Chloride in blood	
Adult:	96–106 milliequivalents per liter (mEq/L) [96–106 millimoles per liter (mmol/L)]
Newborn:	96–113 mEq/L (96–113 mmol/L)

Chloride in urine	
Adult:	140–250 mEq per 24 hours (140–250 mmol per day)
Child (10–14 years):	64–176 mEq/24 hours (64–176 mmol/day)
Child (younger than 6 years):	15–40 mEq/24 hours (15–40 mmol/day)

Abnormal Result

Abnormal results occur when extremely high chloride levels are discovered in the tested samples. This high chloride level may be caused by:

- Dehydration, such as from diarrhea or vomiting.
- Eating a lot of salt.
- Kidney disease.
- An overactive parathyroid gland (hyperparathyroidism).

Abnormal results can also occur when extremely low chloride levels are discovered in the tested samples. This low chloride level may be caused by:

- A condition that raises the pH of the blood above the normal range (metabolic alkalosis).
- Conditions that cause too much water to build up in the body, such as with syndrome of inappropriate antidiuretic hormone secretion (SIADH).
- Addison's disease.
- Ongoing vomiting.

- Heart failure.

Sodium (Na)

Test Overview

A sodium test checks how much sodium is in the blood. Sodium is both an electrolyte and a mineral. It helps keep the water – that is, the amount of fluid inside and outside the body's cells – as well as the electrolyte balance of the body. Sodium is also an important component that determines how nerves and muscles work.

About 85% of the sodium in the body is found in the blood and lymphatic fluid. Sodium levels in the body are partly controlled by a hormone called aldosterone, which is produced by the adrenal glands. Levels of aldosterone inform the kidneys when to retain sodium in the body instead of passing it into the urine. Small amounts of sodium may also be lost through the skin when a person sweats.

Most foods naturally have sodium in them or are part of the ingredient used in cooking. For instance, sodium is found in table salt as sodium chloride or in baking soda as sodium bicarbonate. Additionally, many medicines and other products also have sodium in them, including laxatives, aspirin, mouthwash, and toothpaste.

Low sodium levels have many causes, such as heart failure, malnutrition, or diarrhea.

Why the Test Is Done

A test for sodium may be done to:

- Check the water and electrolyte balance of the body.
- Check the progress of diseases of the kidneys or adrenal glands.
- Find the cause of symptoms from low or high levels of sodium.

How the Test Is Done

Sodium testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Normal:	136–145 milliequivalents per liter (mEq/L) or 136–145 millimoles per liter (mmol/L)

Abnormal Result

Abnormal results occur when extremely high sodium levels are discovered in the tested samples. A high sodium level (hypernatremia) may be caused by:

- High-sodium diet.
- Not drinking enough water and being dehydrated. Dehydration can also be caused by medications (such as diuretics), severe diarrhea or vomiting, kidney disease or injury, Cushing's syndrome, diabetic ketosis, or a condition called diabetes insipidus that makes it difficult to balance water levels in the body.
- High levels of the hormone aldosterone (hyperaldosteronism).

Abnormal results can also occur when extremely low sodium levels are discovered in the tested samples. A low calcium level (hyponatremia) may be caused by:

- Excessive sweating, burns, severe vomiting or diarrhea, drinking too much water (psychogenic polydipsia), or poor nutrition.
- Underactive adrenal glands or thyroid gland, heart failure, kidney disease, cirrhosis, cystic fibrosis, or SIADH (syndrome of inappropriate antidiuretic hormone secretion).

Total Serum Proteins

Test Overview

A serum total protein test measures the amount of protein in the blood. It also measures the amounts of two main groups of proteins in the blood: globulin and albumin:

- Globulin is composed of several proteins called alpha, beta, and gamma. Some globulins are produced by the liver, while others are produced by the immune system. Some globulins have the ability to bind to hemoglobin. Other globulins carry metals, such as iron, in the blood and help fight infection. Serum globulins can be separated into different subgroups by serum protein electrophoresis.
- Albumin is made mainly in the liver. It helps keep the blood from leaking out of blood vessels. Albumin also helps carry some medicines and other substances through the blood and is important for tissue growth and healing.

A test for total serum protein reports separate values for total protein, albumin, and globulin. Some types of globulin (such as alpha-1 globulin) may also be measured.

Why the Test Is Done

Albumin is tested to:

- Check how well the liver and kidneys are working.
- Help determine the cause of swelling of the ankles (edema) or abdomen (ascites) or of fluid collection in the lungs that may cause shortness of breath (pulmonary edema).

- Find out if your diet contains enough protein.

Globulin is tested to:

- See if you have a blood disease, such as multiple myeloma or macroglobulinemia.
- Determine your chances of developing an infection.

How the Test Is Done

Total serum proteins testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Total protein:	6.4–8.3 grams per deciliter (g/dL) or 64–83 grams per liter (g/L)
Albumin:	3.5–5.0 g/dL or 35–50 g/L
Alpha-1 globulin:	0.1–0.3 g/dL or 1–3 g/L
Alpha-2 globulin:	0.6–1.0 g/dL or 6–10 g/L
Beta globulin:	0.7–1.1 g/dL or 7–11 g/L

Abnormal Result

Abnormal results occur when extremely high albumin or globulin levels are discovered in the tested samples.

A high albumin level may be caused by:

- Severe dehydration.

A high globulin level may be caused by:

- Kidney disease.
- Diseases of the blood, such as multiple myeloma, Hodgkin lymphoma, leukemia, macroglobulinemia, or hemolytic anemia.
- Liver disease.
- An autoimmune disease, such as rheumatoid arthritis, lupus, autoimmune hepatitis, or sarcoidosis.
- Tuberculosis.

Abnormal results can also occur when extremely low albumin or globulin levels are discovered in the tested samples.

A low albumin level may be caused by:

- Kidney disease.
- A poor diet (malnutrition).
- Uncontrolled diabetes.
- An autoimmune disease, such as lupus or rheumatoid arthritis.
- Liver disease.
- Heart failure.
- Gastrointestinal malabsorption syndromes, such as sprue or Crohn's disease.
- Hodgkin lymphoma.
- Hyperthyroidism.

Potassium (K)

Test Overview

A potassium test checks how much potassium is in the blood. Potassium is both an electrolyte and a mineral. It helps keep the water – that is, the amount of fluid inside and outside the body's cells – as well as the electrolyte balance of the body. Potassium is also an important component that determines how nerves and muscles work.

Potassium levels often change with sodium levels. When sodium levels go up, potassium levels go down, and when sodium levels go down, potassium levels go up. Potassium levels are also affected by a hormone called aldosterone, which is produced by the adrenal glands.

Potassium levels can also be affected by kidney function, the amount of potassium taken in, blood pH from hormone levels in the body, severe vomiting, and taking certain medications, such as diuretics and potassium supplements. In addition, some cancer treatments that destroy cancer cells can also make potassium levels high.

Why the Test Is Done

A blood test to check potassium is done to:

- Check to see whether treatment for too low or too high potassium levels is working.
- Check levels in people being treated with medicines such as diuretics and for people having kidney dialysis.
- Check people with high blood pressure who may have a problem with their kidneys or adrenal glands.
- Check also if certain cancer treatments are causing too many cells to be destroyed (also called "cell lysis"). Cell lysis syndrome causes very high levels of certain electrolytes, including potassium.
- Check the effects of extra nutrition (total parenteral nutrition [TPN]) on potassium

levels.

How the Test Is Done

Potassium testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Adults:	3.5–5.2 milliequivalents per liter (mEq/L) or 3.5–5.2 millimoles per liter (mmol/L)
Children:	3.4–4.7 mEq/L or 3.4–4.7 mmol/L
Infants:	4.1–5.3 mEq/L or 4.1–5.3 mmol/L
Newborns:	3.7–5.9 mEq/L or 3.7–5.9 mmol/L

Abnormal Result

Abnormal results occur when extremely high potassium levels are discovered in the tested samples. A high potassium level may be caused by:

- taking too many potassium supplements can cause high blood potassium levels.
- Damage or injury to the kidneys. This prevents the kidneys from removing potassium from the blood normally.
- Certain medications, such as aldosterone antagonists and angiotensin-converting enzyme (ACE) inhibitors, can cause high potassium levels.
- Conditions that move potassium from the body's cells into the bloodstream. These conditions include severe burns, heart attack and diabetic ketoacidosis, crush injuries.
- Too much acid (pH) in the blood makes potassium levels higher by causing the potassium in the body's cells to "leak" out of cells and into the blood.

Abnormal results can also occur when extremely low potassium levels are discovered in the tested samples. A low potassium level may be caused by:

- High levels of aldosterone (hyperaldosteronism) made by the adrenal glands.
- Conditions such as severe burns, malnutrition, dehydration, cystic fibrosis, alcohol use disorder, Cushing's syndrome, vomiting, diarrhea, and certain kidney diseases, such as Bartter's syndrome. Bartter's syndrome is a condition characterized by the enlargement of certain kidney cells. It is more common in children and may be linked to abnormally short stature (dwarfism).
- Medicines, such as diuretics, are a common cause of low potassium levels.

Magnesium (Mg)

Test Overview

A magnesium test checks the level of magnesium in your blood. Magnesium is an important electrolyte needed for the proper functioning of muscles, enzymes, and nerves. It also helps the body use energy and is needed to move other electrolytes (sodium and potassium) in and out of cells.

Why the Test Is Done

A blood test to check magnesium is done to:

- Monitor kidney function.
- Find the cause of heart problems or breathing problems, especially in people who have kidney disease.
- Find a cause for nerve and muscle problems, such as muscle twitches, irritability, and muscle weakness.
- Find the cause of symptoms such as low blood pressure, dizziness, nausea, diarrhea, muscle weakness, vomiting, and slurred speech.
- Look for changes in magnesium levels caused by medicines, such as diuretics.
- Find the cause of a low calcium or potassium level that is not improving with treatment.
- Measure levels when magnesium is being given for medical treatment.
- See if people who have heart problems need extra magnesium. Low magnesium levels can increase the chances of life-threatening heart rhythm problems.

How the Test Is Done

Magnesium testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Adult:	1.8–2.6 milligrams per deciliter (mg/dL) [0.74–1.07 millimoles per liter (mmol/L)]
Child:	1.7–2.1 mg/dL (0.70–0.86 mmol/L)
Newborn:	1.5–2.2 mg/dL (0.62–0.91 mmol/L)

Abnormal Result

Abnormal results occur when extremely high magnesium levels are discovered in the tested samples. A high magnesium level may be caused by:

- Taking too many magnesium supplements.
- Having a problem with excreting extra magnesium.
- Specific conditions such as kidney failure and oliguria or low urine production.
- Dehydration.
- Diseases of the adrenal glands, such as Addison's disease.
- An overactive parathyroid gland (hyperparathyroidism).
- An underactive thyroid gland (hypothyroidism).
- Kidney failure.

Abnormal results can also occur when extremely low magnesium levels are discovered in the tested samples. A low magnesium level may be caused by:

- Chronic diarrhea
- Pancreatitis
- Hemodialysis, a mechanical way to filter waste products from the blood when the kidneys don’t function properly
- Uncontrolled diabetes
- Excessive sweating
- Ulcerative colitis (UC)
- Gastrointestinal disorders, such as Crohn’s disease
- Ongoing use of diuretics
- Heavy periods
- Issues involving specific conditions, including cirrhosis, hyperaldosteronism, and hypoparathyroidism
- Severe burns
- Preeclampsia
- Alcohol use disorder

Phosphorus (P)

Test Overview

A phosphorus test checks the level of magnesium in the blood. Phosphorus is an important element that’s vital to several of the body’s physiological processes. It helps with bone growth, energy storage, and nerve and muscle production. Many foods — especially meat and dairy products — contain phosphorus, so it’s usually easy to get enough of this mineral from a diet.
The bones and teeth contain most of the body’s phosphorus. However, the blood also contains

some amount of phosphorus. A medical practitioner can assess an individual's blood phosphorus level using a serum phosphorus test.

Why the Test Is Done

A blood test to check phosphorus levels is done:

- If an individual received abnormal results from a blood calcium test.
- If a medical practitioner suspects that an individual's phosphorus level is too low or too high.

How the Test Is Done

Phosphorus testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Adult	2.5 to 4.5 milligrams of phosphorus per deciliter of blood.
Children:	4.0 to 7.0 mg/dL

Abnormal Result

Abnormal results occur when extremely high phosphorus levels are discovered in the tested samples. A high phosphorus level (hyperphosphatemia) may be caused by:

- Certain medications, such as laxatives that contain phosphates.
- Hypocalcemia, or low serum calcium levels.
- Dietary problems, such as consuming too much phosphate or vitamin D
- Liver disease.
- Diabetic ketoacidosis, which occurs when an individual's body runs out of insulin and begins to burn fatty acids instead.
- Hypoparathyroidism, or impaired parathyroid gland function, leads to low levels of parathyroid hormone.

Abnormal results can also occur when extremely low phosphorus levels are discovered in the tested samples. A low phosphorus level may be caused by:

- Chronic use of antacids.

- Lack of vitamin D.
- Not getting enough phosphorus from a diet.
- Malnutrition.
- Alcoholism.
- Hypercalcemia, or high serum calcium levels.
- Hyperparathyroidism, or overactive parathyroid glands, leads to high levels of parathyroid hormone.
- Severe burns.

Chapter 3: Cardiovascular Testing

Cardiovascular diagnostic and screening tests can provide a lot of information about the electrical activity of the heart, the rhythm of the heartbeat, how well the blood is pumping through the chambers and valves of the heart, how easily the blood is flowing through the coronary arteries to the heart muscle, and also whether there are tumors or other abnormalities in the structure of the cardiovascular system. Cardiovascular testing enables a medical practitioner to determine if an individual is at risk of developing any cardiovascular disease.

Troponin

Test Overview

Troponins are proteins found in the cardiac and skeletal muscles. When the heart is damaged, it releases troponin into the bloodstream. Hence, medical practitioners measure an individual's troponin levels to detect whether they are experiencing or might have experienced a heart attack. A troponin test can also help a medical practitioner find the best treatment sooner.
Troponin proteins are split into three subunits, troponin C (TnC), troponin T (TnT), troponin I (TnI). Measuring cardiac troponin levels in the blood allows medical practitioners to diagnose a heart attack or other heart-related conditions more effectively and thereby provide immediate treatment.

Why the Test Is Done

A blood test to check troponin levels is done:

- To determine the level of troponin in the bloodstream.
- To determine if an individual might have experienced a heart attack or is at the risk of experiencing one.

How the Test Is Done

Troponin testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, a troponin test checks the level of troponin in the blood. Troponin levels are low enough to be undetectable in healthy people. However, high levels of troponin are an immediate red flag. The higher the number, the more troponin — specifically troponin T and I — have been released into the bloodstream, and the higher the likelihood of heart damage.

Normal Result

Normal	0.02 nanograms per milliliter (ng/mL)

Abnormal Result

Abnormal results occur when extremely high troponin levels are discovered in the tested samples. A high troponin level may be caused by:

- Kidney disease
- Hypothyroidism, an underactive thyroid
- Extensive infection, like sepsis
- Heart failure
- Pulmonary embolism, a blood clot in your lungs
- Endocarditis, an infection of the heart valves
- Burns
- Medication
- Myocarditis, an inflammation of the heart muscle
- Pericarditis, an inflammation around the sac of the heart
- Cardiomyopathy, a weakened heart
- Diabetes
- Stroke
- Intestinal bleeding
- Intense exercise

Creatine Phosphokinase (CPK)

Test Overview

Creatine phosphokinase (CPK), or phosphocreatine kinase, also referred to as Creatine kinase (CK), is an enzyme in the body that causes the phosphorylation of creatine. Creatine kinase (CK) is found in the skeletal muscle, cardiac muscle, brain, bladder, stomach, and colon.
CPK can be broken down into three separate parts:

- CPK-1 is mainly found in the brain and lungs.
- CPK-2 is mostly found in the heart.
- CPK-3 is found in the skeletal muscle.

When these parts of the body become damaged due to injury or disease, CPK enzymes can be

released into the bloodstream. Hence, the CPK test checks the levels of these enzymes in the blood. This can help a medical practitioner identify the areas of the body that have been damaged.

Why the Test Is Done

A CPK blood test is done:

- To help diagnose a heart attack
- To ascertain the cause of chest pain
- To assess the extent of damage to heart or muscle tissue
- To determine muscular dystrophy, which is a group of diseases that causes muscle loss and weakness over time

A CPK test can also help detect various muscle diseases or issues, including:

- malignant hyperthermia, which is an inherited disease that causes muscle contractions
- polymyositis, which is an inflammatory disease that causes muscle weakness
- dermatomyositis, which is an inflammatory disease that affects the skin and muscles
- other conditions that may cause muscle breakdowns, such as over-exercising, certain medications, or prolonged seizures

How the Test Is Done

CPK testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, a CPK test checks for the level of CPK enzymes in the blood. It's important to remember that results will vary from person to person, depending on specific injuries and conditions.

Normal Result

Male	39 – 308 U/L
Female	26 – 192 U/L.

Abnormal Result

Abnormal results occur when extremely high CPK levels are discovered in the tested samples.

CPK-1

CPK-1 is found primarily in the brain and lungs. Elevated CPK-1 levels could indicate:

- Brain cancer.
- A brain injury due to stroke or bleeding in the brain.
- A seizure.
- A pulmonary infarction, or the death of lung tissue.

CPK-2

CPK-2 is found mostly in the heart. Elevated levels of CPK-2 can be the result of:

- Injury to the heart due to an accident.
- Inflammation of the heart muscle, which is usually from a virus.
- An electrical injury.
- A heart-attack.

Additionally, increased levels of CPK-2 in the blood can also occur after open-heart surgery and heart defibrillation, which is a medical procedure that involves shocking the heart. After a heart attack, CPK-2 levels in the blood rise, but they usually fall again within 48 hours.

CPK-3

CPK-3 is found in the skeletal muscle. The levels of CPK-3 may rise if the muscles:

- Are damaged from a crush injury, which occurs when a body part has been squeezed between two heavy objects.
- I have been immobile for an extended period.
- Are damaged by illegal drug use.
- Are inflamed.

Other factors that may cause elevated levels of CPK-3 to include:

- Muscular dystrophy
- Seizures
- Muscle trauma, which can occur from participating in contact sports, being burned, or having surgery
- Electromyography, which is a procedure that tests nerve and muscle function

Other factors that can cause elevated levels of CPK include:

- Over-exercising or vigorous exercise
- Cardiac catheterization
- Vaccines
- Recent surgery
- Intramuscular injections

Lactate Dehydrogenase (LDH)

Test Overview

LDH is an enzyme found in almost every cell of the body, including the blood, muscles, brain, kidneys, and pancreas. The enzyme is responsible for converting sugar into energy.

The lactate dehydrogenase (LDH) test looks for signs of damage to the body's tissues. The test is used to measure LDH levels in the blood. However, in certain conditions, doctors may measure LDH levels in the urine or cerebrospinal fluid (CSF)

When cells are damaged or destroyed, this enzyme is released into the fluid portion of blood. LDH can also be released into other body fluids, including cerebrospinal fluid, which surrounds the brain and spinal cord.

There are five different forms of LDH that are called isoenzymes. They are distinguished by slight differences in their structure. The isoenzymes of LDH are LDH-1, LDH-2, LDH-3, LDH-4, and LDH-5. These different LDH isoenzymes are found in different body tissues. The areas of highest concentration for each type of isoenzyme are:

- LDH-1: heart and red blood cells
- LDH-2: heart and red blood cells
- LDH-3: lymph tissue, lungs, platelets, pancreas
- LDH-4: liver and skeletal muscle
- LDH-5: liver and skeletal muscle

Why the Test Is Done

A blood test to check LDH levels is done:

- To measure whether an individual has tissue damage and, if so, how much
- To monitor severe infections or conditions like hemolytic or megaloblastic anemias, kidney disease, and liver disease
- To help evaluate certain cancers or evaluate a cancer treatment an individual might be undergoing

Depending on an individual's condition, they may need to have LDH tests on a regular basis.

A fluid body test to check for LDH levels may be done to:

- Find the cause of fluid buildup, which could be due to many things, like injury and inflammation. (It could also be brought on by an imbalance in the pressure within blood vessels and the amount of protein in the blood.)
- Help determine if an individual has bacterial or viral meningitis.

How the Test Is Done

LDH testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

LDH levels vary by age and laboratory. Infants and young children will have much higher normal LDH levels than older children or adults. LDH is often reported in units per liter (U/L).

Normal Result

LDH in blood	
0 to 10 days	290–2000 U/L
10 days to 2 years	180–430 U/L
2 to 12 years	110–295 U/L
Older than 12 years	100–190 U/L

LDH in cerebrospinal fluid

Newborns	70 U/L or lower
Adults	40 U/L or lower

Abnormal Result

Abnormal results occur when extremely high LDH levels are discovered in the tested samples. High levels of LDH indicate some form of tissue damage. High levels of more than one isoenzyme may indicate more than one cause of tissue damage. For example, a patient with pneumonia could also have a heart attack. Extremely high levels of LDH could indicate severe disease or multiple organ failure. A high LDH level may be caused by:

- Blood flow deficiency.
- Cerebrovascular accident, also known as a stroke.
- Liver disease, such as hepatitis.
- Heart attack.
- Sepsis and septic shock.
- Hemolytic anemia.
- Muscle injury.
- Muscular dystrophy.
- Pancreatitis.
- Infectious mononucleosis.
- Tissue death.
- Excessive use of alcohol.

Abnormally low LDH levels rarely occur and usually aren’t considered harmful.

Brain Natriuretic Peptide (BNP)

Test Overview

The test measures the levels of BNP hormone in the blood. During heart failure, pressure builds up in the chambers of the heart , and this creates BNP. When the heart works harder and doesn't pump blood well, it releases this hormone in large amounts. BNP widens your blood vessels to help improve circulation. Hence, the presence of higher levels in the blood may be a sign of heart failure.

Why the Test Is Done

A blood test to check for BNP levels is done:

- If an individual is showing symptoms of heart failure such as shortness of breath or extreme fatigue.
- To ascertain whether an individual has heart failure or pneumonia.
- To determine a patient's outlook after heart failure, a high level equates to a worse outcome.
- After a heart failure diagnosis to determine how well treatment is working.
- To determine when it is safe for an individual to check out of the hospital

How the Test Is Done

BNP testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, a BNP test checks the level of BNP in the blood. Generally, BNP levels below 100 picograms per milliliter (pg/ml) are considered normal. However, levels above 400 pg/ml are considered high.

Normal Result

BNP

Normal BNP levels may vary depending on your age and sex:

Age	Men	Women
Less than 45 years old	35 pg/ml or below	64 pg/ml or below
46-60 years old	36-52 pg/ml	46-60 pg/ml
61-82 years old	53-91 pg/ml	96-163 pg/ml
83 years old or older	93 pg/ml or below	167 pg/ml or below

Abnormal Result

Abnormal results occur when extremely high BNP levels are discovered in the tested samples. A high BNP level may be caused by:

- Pneumonia
- Kidney failure or dialysis use
- Severe lung disease
- COPD (chronic obstructive pulmonary disease)
- Coronary artery disease
- Atrial fibrillation
- Pre-existing heart failure
- High blood pressure
- An overactive thyroid
- High levels of the stress hormone cortisol
- Certain rare tumors
- Brain hemorrhages
- A liver disease called cirrhosis
- Chemotherapy

Chapter 4: Endocrine Tests

Adrenocorticotropic Hormone (ACTH)

An ACTH test measures ACTH and cortisol levels in the blood and helps the doctor identify diseases that are associated with too much or too little cortisol in our bodies. Possible causes of these diseases include pituitary or adrenal malfunction, adrenal tumor, pituitary tumor, and lung cancer.

Why the Test Is Done

An ACTH test is done if an individual has symptoms of too much or too little cortisol. These symptoms can vary widely from person to person and are often a sign of additional health problems.

How the Test Is Done

The test is usually done first thing in the morning because ACTH levels are highest when an individual wakes up in the morning. Therefore, the test is usually scheduled very early in the morning.
ACTH testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Normal	9-52 pictogram per milliliter

Abnormal Result

Abnormal results occur when extremely high or low ACTH levels are discovered in the tested samples. A high level of ACTH may be a sign of:

- Adrenal hyperplasia
- Cushing's disease
- An ectopic tumor that produces ACTH
- Addison's disease
- Adrenoleukodystrophy, which is very rare
- Nelson's syndrome, which is very rare

A low level of ACTH may be a sign of:

- adrenal tumor
- hypopituitarism
- exogenous Cushing's syndrome

Dexamethasone Suppression Test

A dexamethasone suppression test is used to measure whether the adrenocorticotropic hormone (ACTH) secretion by the pituitary gland can be suppressed. Dexamethasone is a human-made (synthetic) steroid that binds to the same receptor as cortisol. Dexamethasone is used to reduce ACTH release in normal people. Therefore, taking dexamethasone should reduce ACTH levels and lead to a decreased cortisol level. The low-dose test can help tell whether an individual's body is producing too much ACTH, while the high-dose test can help determine whether the problem is in the pituitary gland.

Why the Test Is Done

A dexamethasone suppression test is done:

- When the provider suspects that an individual's body is producing too much cortisol.
- To help diagnose Cushing syndrome and identify the cause.

How the Test Is Done

During this test, the patient will be given dexamethasone. This is a strong man-made (synthetic) glucocorticoid medicine. Afterward, such patient's blood will be drawn so that the cortisol level in their blood can be measured.

There are two different types of dexamethasone suppression tests: low dose and high dose. Each type can either be done in an overnight (common) or standard (3-day) method (rare). There are different processes that may be used for either test. Examples of these are described below.

Common:

- **Low dose overnight**: The patient will get 1 milligram (mg) of dexamethasone at 11 p.m., and a health care provider will draw their blood the next morning at 8 a.m. for a cortisol measurement.
- **High dose overnight**: The healthcare provider will measure the patient's cortisol level on the morning of the test. Then the patient will receive 8 mg of dexamethasone at 11 p.m. The patient's blood will be drawn the next morning at 8 a.m. for a cortisol measurement.

Rare:

- **Standard low-dose**: Urine is collected over 3 days (stored in 24-hour collection containers) to measure cortisol. On day 2, the patient will get a low dose (0.5 mg) of dexamethasone by mouth every 6 hours for 48 hours.

- **Standard high-dose:** Urine is collected over 3 days (stored in 24-hour collection containers) for measurement of cortisol. On day 2, the patient will receive a high dose (2 mg) of dexamethasone by mouth every 6 hours for 48 hours.

Results

Normal Results

Low dose:

Overnight - 8 a.m.	Plasma cortisol lower than 1.8 micrograms per deciliter (mcg/dL) or 50 nanomoles per liter (nmol/L)
Standard	Urinary free cortisol on day 3 lower than 10 micrograms per day (mcg/day) or 280 nmol/L

High dose:

Overnight	Greater than 50% reduction in plasma cortisol
Standard	Greater than 90% reduction in urinary free cortisol

Abnormal Results

An abnormal response to the low-dose test may mean that the patient has an abnormal release of cortisol (Cushing syndrome). This could be due to:

- The adrenal tumor that produces cortisol
- A pituitary tumor that produces ACTH
- Tumor in the body that produces ACTH (ectopic Cushing syndrome)

The high-dose test can help tell a pituitary cause (Cushing disease) from other causes. An ACTH blood test may also help identify the cause of high cortisol.
Abnormal results vary based on the condition causing the problem.

Cushing syndrome caused by an adrenal tumor:

- Low-dose test: No decrease in blood cortisol
- ACTH level: Low
- In most cases, the high-dose test is not needed

Ectopic Cushing syndrome:

- Low-dose test: No decrease in blood cortisol
- ACTH level: High
- High-dose test: No decrease in blood cortisol

Cushing syndrome caused by a pituitary tumor (Cushing disease)

- Low-dose test: No decrease in blood cortisol
- High-dose test: Expected decrease in blood cortisol

Aldosterone (ALD)

Test Overview

An aldosterone test – also known as a serum aldosterone test – measures the amount of ALD in the blood. ALD is a hormone made by the adrenal glands. ALD affects blood pressure and also regulates sodium (salt) and potassium in the blood, among other functions.

Why the Test Is Done

A blood test to check ALD levels is done:

- To diagnose fluid and electrolyte disorders
- To diagnose overproduction of ALD
- To diagnose high blood pressure that is hard to control or occurs at a young age
- To diagnose orthostatic hypotension (low blood pressure caused by standing up)
- To diagnose adrenal insufficiency (underactive adrenal glands)

How the Test Is Done

ALD levels vary throughout the day, and the levels are highest in the morning. Hence, the timing of the test is very important.
ALD testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Normal	2-9 ng/dl (55 - 250 pmol/L)

Abnormal Result

Abnormal results occur when extremely high or low ALD levels are discovered in the tested samples. High levels of ALD are also called hyperaldosteronism. This can increase sodium in the blood and lower potassium in the blood. Hyperaldosteronism can be caused by:

- Renal artery stenosis (narrowing of the artery that supplies blood to the kidney)
- Kidney disease or failure
- Congestive heart failure
- Conn syndrome, Cushing’s syndrome, or Bartter syndrome (rarely)

- Cirrhosis (scarring of the liver) toxemia of pregnancy
- A diet extremely low in sodium

Low ALD levels are called hypoaldosteronism. Symptoms of this condition include:

- Low blood pressure
- Dehydration
- Low potassium levels
- Low sodium levels

Hypoaldosteronism can be caused by:

- Adrenal insufficiency
- Addison's disease, which affects adrenal hormone production
- Hyporeninemic hypoaldosteronism (low ALD caused by kidney disease)
- A diet very high in sodium (more than 2,300 mg/ day for those age 50 and under; 1,500 over age 50)
- Congenital adrenal hyperplasia (a congenital disorder in which infants lack the enzyme needed to make cortisol, which can also affect ALD production)

Cortisol Level

Test Overview

A cortisol level test – also called a serum cortisol test – measures the level of cortisol present in the blood.

Why the Test Is Done

A blood test to check cortisol levels is done:

- To check if the cortisol production levels in an individual are either too high or too low.
- To diagnose certain diseases such as Addison's disease and Cushing's disease.
- To assess the functioning of the adrenal and pituitary glands.

How the Test Is Done

Just like ALD, cortisol levels vary throughout the day, and the levels are highest in the morning. Hence, the timing of the test is very important.
Cortisol testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

The normal level for a blood sample was taken before 8 a.m.	6 - 23 micrograms per deciliter (mcg/dL)

Abnormal Result

Abnormal results occur when extremely high or low cortisol levels are discovered in the tested samples.
Higher-than-normal cortisol levels may indicate that:

- The pituitary gland is releasing too much ACTH due to a tumor or excess growth of the pituitary gland
- A tumor is present in the adrenal gland, resulting in excess cortisol production.
- A tumor is present elsewhere in the body that's involved in cortisol production.

Lower-than-normal cortisol levels may indicate that:

- The patient has Addison's disease, which occurs when the production of cortisol by the adrenal glands is too low.
- The patient has hypopituitarism, which occurs when the production of cortisol by the adrenal glands is too low because the pituitary gland is not sending proper signals.

Estradiol Test

Test Overview

An estradiol test measures the amount of the hormone estradiol in the blood. It is also called an E2 test. Estradiol is a form of the hormone estrogen; the ovaries, breasts, and adrenal glands make estradiol. Estradiol helps with the growth and development of female sex organs, including the uterus, fallopian tubes, vagina, and breasts.
Estradiol helps to control the way fat is distributed in the female body. It is also essential for bone and joint health in females. Males also have estradiol in their bodies. However, their levels of estradiol are lower than the levels in females. In males, the adrenal glands and testes make estradiol. Estradiol has been shown in vitro to prevent the destruction of sperm cells, but its clinical importance in sexual function and development in men is likely less significant than in women. Hence, this test is mostly conducted on women.

Why the Test Is Done

A blood test to check estradiol levels is done:

- If female or male sex characteristics aren't developing at the normal rate.

- To check for causes of abnormal menstrual periods.
- To check for causes of abnormal vaginal bleeding.
- To check for infertility in women.
- To determine if an individual is preparing to enter menopause or if they are already going through the transition.
- To indicate how well the ovaries are working.

How the Test Is Done

Estradiol testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Menstruating women	15 to 350 picograms per milliliter (pg/mL)
Postmenopausal women	lower than 10 pg/mL

Abnormal Result

Abnormal results occur when extremely high or low estradiol levels are discovered in the tested samples.
Estradiol levels that are higher than normal may suggest:

- Early puberty
- Cirrhosis, which is scarring of the liver
- Hyperthyroidism, which is caused by an overactive thyroid gland
- Tumors in the ovaries or testes
- Gynecomastia, which is the development of breasts in men

Lower-than-normal levels of estradiol may suggest:

- Menopause
- Ovarian failure, or premature menopause, occurs when the ovaries stop functioning before the age of 40
- Polycystic ovarian syndrome (PCOS), a hormone disorder with a wide range of symptoms that are also believed to be a leading cause of infertility in women
- Hypogonadism, which occurs when the ovaries or testes don’t produce enough hormone
- Depleted estrogen production, which can be caused by low body fat
- Turner syndrome, which is a genetic disorder in which a female has one X chromosome instead of two

- Hypopituitarism

Growth Hormone Test

Test Overview

Growth hormone (GH) is one of the hormones produced by the pituitary gland in the brain. It is also known as human growth hormone (HGH) or somatotropin.

GH plays an important role in normal human growth and development, especially in children and adolescents. GH levels that are higher or lower than they should lead to health problems in both children and adults.

Why the Test Is Done

Too much or too little HGH can lead to a variety of issues, including:

- Dwarfism
- Fatigue
- Bone weakness
- Delayed puberty
- Low energy
- Less strength
- The decline in muscle mass
- Increase in body fat

Hence, a test to check growth hormone levels is done if an individual has any of these conditions.

How the Test Is Done

HGH testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, an HGH test measures the amount of HGH in the blood.

Normal Result

For suppression tests	0.3 nanograms per milliliter (ng/mL) or below
For stimulation tests	4 - 5 ng/mL

Abnormal Result

Abnormal results occur when extremely high or low HGH levels are discovered in the tested samples.
High levels of GH may suggest:

- Possible acromegaly
- Gigantism (in children, it can cause very long bones, delayed puberty, and other problems)
- A tumor

Low levels may indicate:

- Possible dwarfism
- Slow growth
- Hypopituitarism, which means the pituitary gland isn't working as well as it should

Luteinizing Hormone (LH)

Test Overview

Luteinizing hormone (LH) is an important hormone produced in both men and women. This hormone is known as gonadotropin, and it affects the sex organs in both men and women. It affects ovaries in women, while it affects the testes in men. LH plays a role in puberty, menstruation, and fertility. The amount of LH in the blood can indicate underlying problems associated with a variety of reproductive health issues.
An LH blood test measures the amount of LH in the bloodstream. In a woman, the amount of this hormone in the bloodstream varies with age and throughout the menstrual cycle. It also changes with pregnancy. For a man, a healthcare practitioner can order an LH test to establish a baseline LH level.

Why the Test Is Done

Levels of LH relate to menstrual issues, fertility, and the onset of puberty. Hence, a blood test to check LH levels is done:

- If a woman is having difficulty getting pregnant
- If a woman has irregular or absent menstrual periods
- If it is suspected that a woman has entered menopause

- If a man has signs of low testosterone levels, such as low muscle mass or a decrease in sex drive
- If a pituitary disorder is suspected
- If a boy or girl appears to be entering puberty too late or too soon

How the Test Is Done

LH testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, an LH test measures the amount of LH in the blood.

Normal Result

The following values are normal LH blood levels measured in international units per liter (IU/L):

Women in the follicular phase of the menstrual cycle	1.9 to 12.5 IU/L
Women at the peak of the menstrual cycle	8.7 to 76.3 IU/L
Women in the luteal phase of the menstrual cycle	0.5 to 16.9 IU/L
Pregnant women	Less than 1.5 IU/L
Women past menopause	15.9 to 54.0 IU/L
Women using contraceptives	0.7 to 5.6 IU/L
Men between the ages of 20 and 70	0.7 to 7.9 IU/L
Men over 70	3.1 to 34.0 IU/L

Each result can vary based on the patient's unique condition; some general interpretations of LH results can include the following.

For women

Increased levels of LH and FSH can indicate a problem with the ovaries. This is known as a primary ovarian failure. Some causes of primary ovarian failure can include:

- Ovaries that are not properly developed
- Autoimmune disorders
- Genetic abnormalities, such as Turner syndrome

- Polycystic ovary syndrome (PCOS)
- Exposure to radiation
- History of taking chemotherapy drugs
- Ovarian tumor
- Thyroid or adrenal disease

Low levels of both LH can indicate secondary ovarian failure. This means that another part of the body causes ovarian failure. In many cases, this is the result of problems with the areas of the brain that make hormones, such as the pituitary gland.

For men

High LH levels can indicate primary testicular failure. The causes of this condition can include:

- Chromosome abnormalities, such as Klinefelter syndrome
- Gonad development failure
- A history of viral infections, such as the mumps
- Trauma
- Radiation exposure
- History of taking chemotherapy medications
- Autoimmune disorders
- Tumors, such as a germ cell tumor

Secondary testicular failure can also be due to a brain-related cause, such as a disorder in the hypothalamus. Low levels of LH in adult males may lead to low testosterone levels, potentially causing such symptoms as:

- Sexual dysfunction
- Lack of sexual interest
- Fatigue

For children

High levels of LH can cause early puberty. This is known as precocious puberty, and girls are more likely to experience this condition than boys. Underlying causes of this can include:

- A tumor in the central nervous system
- Trauma or brain injury
- Inflammation or infection in the central nervous system, such as meningitis or encephalitis
- A history of brain surgery
- A history of irradiation to the brain

Delayed puberty with normal or lower LH levels can indicate underlying disorders, including:

- Ovarian or testicular failure
- Hormone deficiency

- Turner syndrome
- Klinefelter syndrome
- Chronic infection
- Cancer

Medications that can change LH levels include:

- Anticonvulsants
- Clomiphene
- Digoxin
- Hormone treatments
- Birth control pills

Parathyroid Hormone (PTH)

Test Overview

The parathyroid glands located in the neck at the edge of the thyroid gland release a hormone called parathyroid hormone (PTH), also known as parathormone. This hormone helps regulate calcium levels in the blood.

Calcium levels in the blood inform the parathyroid glands to release or suppress PTH; therefore, calcium imbalances in the blood can be a sign of parathyroid gland or PTH problems. When calcium levels are low, the parathyroid glands increase PTH production. When calcium levels are high, the glands slow the secretion of PTH. Therefore, a PTH test is conducted to check the level of PTH in the blood.

Why the Test Is Done

This test may be done in order to:

- Check parathyroid function
- Distinguish between parathyroid-related and non-parathyroid-related disorders
- Monitor the effectiveness of treatment in parathyroid-related issues
- Determine the cause of low phosphorus levels in the blood
- Determine why severe osteoporosis isn’t responding to treatment
- Monitor chronic conditions, such as kidney disease.

How the Test Is Done

PTH testing requires a blood sample. Hence, the health professional will take a blood sample,

and then the sample will be sent to the lab for analysis.

Results

Basically, a PTH test measures the amount of PTH in the blood.

Normal Result

Intact (whole)	10-65 pg/mL or 10-65 ng/L (SI units)
N terminal	8-24 pg/mL
C terminal	50-330 pg/mL

Abnormal Result

Abnormal results occur when extremely high or low PTH levels are discovered in the tested samples.
High levels of PTH may indicate:

- Hyperparathyroidism, which is commonly due to a benign parathyroid tumor
- Conditions that cause increased phosphorus levels, like chronic kidney disease
- That the body isn't responding to PTH (pseudohypoparathyroidism)
- Swelling or tumors in the parathyroid glands
- Pregnancy or breastfeeding in a woman; is mostly uncommon
- A lack of calcium.
- Vitamin D disorders.

Thyroid Function

Test Overview

Thyroid function tests are a series of blood tests used to measure the functioning of the thyroid gland. Available tests include T3, T4, TSH, and T3RU.
The thyroid is a small gland located in the lower front of the neck and is responsible for helping to regulate several processes in the body, such as metabolism, mood, and energy generation. The thyroid gland produces two main hormones: triiodothyronine (T3) and thyroxine (T4).
Hence, a thyroid function test can be used to determine the level of these hormones in the body.

Why the Test Is Done

This test may be done to:

- Determine how well the thyroid gland is working.
- Gauge the level of the two major thyroid hormones.

How the Test Is Done

Thyroid function testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, a Thyroid function test is used to determine how well the thyroid gland is working.

Normal Result

Thyroxine	0.4 – 4.0 milli-international units of hormone per liter of blood (mIU/L)
Triiodothyronine	100 – 200 nanograms of hormone per deciliter of blood (ng/dL)

Abnormal Result

Abnormally high levels most commonly indicate a condition called Grave's disease. This is an autoimmune disorder associated with hyperthyroidism.

Testosterone (T)

Test Overview

Testosterone is responsible for certain features of our bodies, such as hair, muscle mass, and strength. Men with low testosterone levels may notice a reduction in these traits, while women with too much testosterone may notice an increase in these traits. Hence, a testosterone test is used to determine the level of testosterone in the body.

Why the Test Is Done

This test may be done to:

- If an individual believes their testosterone levels aren't within a normal range.

How the Test Is Done

The test is usually performed in the morning when testosterone levels are highest. Sometimes, the test needs to be retaken to confirm the measurements.
Testosterone testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Men	300 – 1,000 nanograms per deciliter (ng/dL)
Women	15 – 70 ng/dL

Chapter 5: Liver and Kidney Function

Kidney Function Test

A kidney function test is a series of tests done to check how well the kidney is functioning. Testing is usually done if an individual has other conditions that can harm the kidneys, such as diabetes or high blood pressure. The test can help medical practitioners monitor these conditions. The different types of test conducted under a kidney function test include:

- Blood urea nitrogen
- Creatinine blood test
- Glomerular filtration rate

Blood Urea Nitrogen (BUN)

Test Overview

A blood urea nitrogen (BUN) test is used to determine how well the kidneys are working. It does this by measuring the amount of urea nitrogen in the blood. The blood urea nitrogen (BUN) test also checks for waste products in the blood. It's often done along with other blood tests, such as a creatinine blood test, to make a proper diagnosis.

Why the Test Is Done

A blood urea nitrogen test can help diagnose the following conditions:

- Liver damage
- Malnutrition
- Poor circulation
- Dehydration
- Urinary tract obstruction
- Congestive heart failure
- Gastrointestinal bleeding

How the Test Is Done

BUN testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, a BUN test measures the amount of urea nitrogen in the blood. Results of a BUN test are measured in milligrams per deciliter (mg/dL). Normal BUN values tend to vary depending on gender and age.

Normal Result

Adult men	8 to 24 mg/dL
Adult women	6 to 21 mg/dL
Children (1 – 17 years old)	7 to 20 mg/dL

Abnormal Results

Abnormal results occur when extremely high or low BUN levels are discovered in the tested samples.
Higher BUN levels can indicate:

- Heart disease
- Gastrointestinal bleeding
- Congestive heart failure
- Dehydration
- Obstruction in the urinary tract
- High protein levels
- Kidney disease
- Kidney failure
- A recent heart attack
- Stress
- Shock

Lower BUN levels can indicate:

- Liver failure
- Severe lack of protein in the diet
- Malnutrition
- Overhydration

Glomerular Filtration Rate

Test Overview

Glomeruli are the small filters inside the kidneys. If the kidneys aren't working properly, the glomeruli won't filter as efficiently. A medical practitioner may order a glomerular filtration rate (GFR) test if they suspect an individual's kidneys aren't working properly.

Why the Test Is Done

The GFR test can indicate how well the kidneys are functioning. A medical practitioner may order a GFR test if an individual has the following conditions:

- Diabetes
- Recurring urinary tract infections
- Hypertension
- Heart disease
- Difficulty with urination
- Blood in the urine
- Kidney stones
- Polycystic kidney disease
- Kidney failure

How the Test Is Done

GFR testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Basically, a GFR test measures the amount of the waste product creatinine in the blood.

	Normal Result
Normal levels	90 or above

Creatinine Blood Test

Test Overview

A creatinine blood test measures the level of creatinine in the blood. Creatinine levels in the

blood can provide a medical practitioner with information about how well the kidneys are working. Creatinine blood tests are usually performed along with several other laboratory tests, including a blood urea nitrogen (BUN) test.

Why the Test Is Done

A creatinine blood test can be done to assess the creatinine levels of an individual if they show signs of kidney disease. These symptoms include:

- Fatigue and trouble sleeping
- A loss of appetite
- Lower back pain near the kidneys
- Swelling in the face, wrists, ankles, or abdomen
- Changes in urine output and frequency
- Nausea
- High blood pressure
- Vomiting

How the Test Is Done

Creatinine blood testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Men	0.9 to 1.3 mg/dL
Women	0.6 to 1.1 mg/dL

Abnormal Results

Abnormal results occur when extremely high creatinine levels are discovered in the tested samples. High serum creatinine levels in the blood indicate that the kidneys aren’t functioning properly.

Creatinine levels may be slightly elevated or higher than normal due to:

- A blocked urinary tract

- A high-protein diet
- Reduced blood flow to the kidneys due to shock, complications of diabetes, or congestive heart failure
- Kidney problems, such as kidney damage or infection
- Dehydration

Liver Function Tests

Liver function tests help determine the health of the liver by measuring the levels of proteins, liver enzymes, and bilirubin in the blood.
A liver function test is often recommended in the following situations:

- To check for damage from liver infections, such as hepatitis B and hepatitis C
- To monitor the side effects of certain medications known to affect the liver
- If an individual already has liver disease, to monitor the disease and to check how well a particular treatment is working
- If an individual is experiencing the symptoms of a liver disorder
- If an individual has gallbladder disease

Many tests can be performed on the liver as certain tests can reflect different aspects of liver function. Commonly used tests to check liver abnormalities are:

- Alanine transaminase (ALT)
- Aspartate aminotransferase (AST)
- Alkaline phosphatase (ALP)
- Albumin
- Bilirubin

Aspartate Aminotransferase (AST)

Test Overview

An older name for this test is serum glutamic-oxaloacetic transaminase (SGOT). The aspartate aminotransferase (AST) test is a blood test that checks for liver damage. The AST test measures the amount of AST in the blood that has been released from injured tissues.
AST is found in the highest concentrations in the liver, muscles, heart, kidney, brain, and red blood cells. A small amount of AST is typically in the bloodstream; however, higher-than-normal amounts of this enzyme in the blood may be a sign of a health problem, and abnormal levels can be associated with liver injury.

Why the Test Is Done

A blood test to check AST levels is done:

- If an individual is experiencing the symptoms of liver disease such as fatigue, weakness, a loss of appetite, nausea, vomiting, swelling of the abdomen, jaundice, dark urine, severe skin itching or pruritus, bleeding difficulties, and abdominal pain.
- To see if treatments you take for liver disease are working.
- To check that medications are not causing liver damage.
- To check if other health conditions are affecting an individual's liver.

How the Test Is Done

AST testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Males	10 to 40 units/L
Females	9 to 32 units/L

Abnormal Result

Abnormal results occur when extremely high AST levels are discovered in the tested samples. Higher-than-normal AST levels can be caused by:

- Chronic (ongoing) hepatitis
- Blockage in the bile ducts that carry digestive fluid from the liver to the gallbladder and intestine
- Cirrhosis (long-term damage and scarring of the liver)
- Liver cancer

Abnormally high AST levels can be caused by:

- Acute viral hepatitis
- A blockage in blood flow to the liver
- Damage to the liver from drugs or other toxic substances

Alanine Aminotransferase (ALT)

Test Overview

An older name for this test is serum glutamic-pyruvic transaminase (SGPT). An alanine aminotransferase (ALT) test measures the level of ALT in the blood. ALT is an enzyme made by cells in the liver. ALT is normally found inside liver cells. However, when the liver is damaged or inflamed, ALT can be released into the bloodstream. This causes serum ALT levels to rise. Measuring the level of ALT in an individual's blood can help medical practitioners evaluate liver function or determine the underlying cause of a liver problem. The ALT test is often part of an initial screening for liver disease.

Why the Test Is Done

The ALT test is usually used to determine whether someone has a liver injury or liver failure. A medical practitioner may order an ALT test if an individual is having symptoms of liver disease, such as:

- Jaundice, which is a yellowing of the eyes or skin
- Dark urine
- Nausea
- Vomiting
- Pain in the right upper quadrant of the abdomen

An ALT test may also be performed to:

- Monitor the progression of liver diseases, such as hepatitis or liver failure
- Evaluate how well treatment is working
- Assess whether treatment for liver disease should be started

How the Test Is Done

ALT testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Males	29 to 33 units per liter (IU/L)
Females	19 to 25 IU/L

Abnormal result

Abnormal results occur when extremely high ALT levels are discovered in the tested samples. Higher-than-normal levels of ALT can indicate liver damage.

Increased levels of ALT may be a result of:

- Hepatitis, which is an inflammatory condition of the liver
- Death of liver tissue
- A tumor or cancer in the liver
- Cirrhosis, which is severe scarring of the liver
- A lack of blood flow to the liver
- Mononucleosis, which is an infection usually caused by the Epstein-Barr virus
- Hemochromatosis, which is a disorder that causes iron to build up in the body
- Pancreatitis, which is an inflammation of the pancreas
- Diabetes

Lower-level ALT results indicate a healthy liver.

Alkaline Phosphatase Level (ALP)

Test Overview

An alkaline phosphatase level test (ALP) measures the amount of alkaline phosphatase enzyme in the bloodstream. The test requires a simple blood draw and is often a routine part of other blood tests.

Why the Test Is Done

An ALP test may be performed to determine how well the liver and gallbladder are functioning or to identify problems with the bones.

How the Test Is Done

ALP testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Normal range	20 to 140 IU/L

Abnormal Result

Abnormal results occur when extremely high or low ALP levels are discovered in the tested samples.
Higher-than-normal levels of ALP in the blood may indicate:

- A problem with the liver or gallbladder. This could include hepatitis, cirrhosis, liver cancer, gallstones, or a blockage in the bile ducts.
- An issue related to the bones such as rickets, Paget's disease, bone cancer, or an overactive parathyroid gland.
- Heart failure, kidney cancer, other cancer, mononucleosis, or bacterial infection.

Having lower-than-normal ALP levels in the blood is rare, but it can indicate malnutrition, which could be caused by celiac disease or a deficiency in certain vitamins and minerals.

Albumin Test

Test Overview

A serum albumin test is a simple blood test that measures the amount of albumin in the blood. Having surgery, getting burned, or having an open wound increases the chances of having a low albumin level. If none of those apply to an individual and they have an abnormal albumin level, it may be a sign that their liver or kidneys aren't working correctly.

Why the Test Is Done

An albumin test is done to check how well the liver is working. It's often one of the tests in a liver panel.

How the Test Is Done

Albumin testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Normal range	3.4 to 5.4 grams per deciliter

Low albumin levels can indicate a number of health conditions, including:

- Liver disease

- Inflammation
- Shock
- Malnutrition
- Nephritic syndrome or nephrotic syndrome
- Crohn’s disease
- Celiac disease

Ammonia Test

Test Overview

The ammonia test is a simple blood test that measures how much ammonia is in the blood.

Why the Test Is Done

This test may be done if an individual has a condition that may cause a toxic buildup of ammonia. It is most commonly used to diagnose and monitor hepatic encephalopathy, a severe liver disease.

How the Test Is Done

Ammonia testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Normal range	15 to 45 µ/dL (11 to 32 µmol/L)

Abnormal Result

Abnormal results mean a patient has a higher-than-normal level of ammonia in their blood. This may be due to any of the following:

- Gastrointestinal (GI) bleeding, usually in the upper GI tract
- Genetic diseases of the urea cycle

- High body temperature (hyperthermia)
- Kidney disease
- Liver failure
- Low blood potassium level
- Reye syndrome
- Salicylate poisoning
- Severe muscle exertion
- Ureterosigmoidostomy
- Urinary tract infection with a bacterium called *Proteus mirabilis*

Hepatitis A (Hep A)

Test Overview

This test detects antibodies that are present in the blood produced by the immune system in response to hepatitis A infection. A few different versions of the test can be used to detect different classes of antibodies to hepatitis A.

- -The HAV, IgM antibody test, detects is the first antibody produced by the body when it is exposed to hepatitis A. This test is used to detect early or recent infections and to diagnose disease in people with symptoms of acute hepatitis. It can also be performed as part of an acute viral hepatitis panel.
- The HAV IgG test is designed to detect IgG antibodies that develop over the course of the disease. IgG antibodies remain present for many years, usually a lifetime, providing protection against recurrent infections by the same virus. IgG testing is used to detect past HAV infections and occasionally can be used to determine if an individual has developed immunity from a previous infection, in which case a vaccine is not necessary.
- The HAV total antibody test detects both IgM and IgG antibodies and, therefore, can be used to identify both current and past infections. This test will also be positive after receiving the vaccine, so it can sometimes be used to determine if a person has developed immunity after vaccination, although this practice is not recommended.

Why the Test Is Done

This test can be done:

- To help diagnose the cause of acute hepatitis.
- When an individual is likely to have been exposed to the virus regardless of whether symptoms are present or not.

- As part of the viral hepatitis panel to identify the type of hepatitis virus causing an infection.
- Sometimes to evaluate the need for the hepatitis A vaccine.

Testing for the presence of IgM antibodies to hepatitis A can also be done when an individual has acute symptoms such as:

- Fever
- Fatigue
- Loss of appetite
- Nausea, vomiting, abdominal pain
- Dark urine and/or pale-colored stool
- Joint pain
- Jaundice

How the Test Is Done

Hepatitis testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Results of hepatitis testing may indicate the following:

HAV IgM	HAV IgG or Total Antibody (IgM and IgG)	Results Indicate
Positive	Not Performed	Acute or recent HAV infection
Negative	Positive	No active infection but previous HAV exposure; have developed immunity to HAV or recently vaccinated for HAV
Not Performed	Positive	Has been exposed to HAV but does not rule out acute infection
Not Performed	Negative	No current or previous HAV infection; vaccine may be recommended if at risk

A total antibody test detects both IgM and IgG antibodies but does not distinguish between them. If the total antibody test or hepatitis An IgG result is positive and an individual has never been vaccinated against HAV, then such individual has had past exposure to the virus.

Hepatitis B (Hep B)

Test Overview

Hepatitis B blood tests are used to detect viral proteins (antigens), antibodies that are produced in response to infection, or to evaluate the genetic material (DNA) of the virus. The pattern of test results can identify a person who has an active ongoing infection, has been exposed to HBV in

the past, or has developed an immune response as a result of vaccination.
Three different tests can be conducted for Hepatitis B. A **hepatitis B surface antigen test** shows if an individual is contagious. A positive result means an individual has hepatitis B and can spread the virus. A negative result means an individual doesn't currently have hepatitis B. A **hepatitis B core antigen test** shows whether an individual is currently infected with HBV. Positive results usually mean an individual has acute or chronic hepatitis B. A **hepatitis B surface antibody test** is used to check for immunity to HBV. A positive test means an individual is immune to hepatitis B.

Why the Test Is Done

The test is done primarily to screen for and diagnose acute or chronic hepatitis B virus (HBV) infection, to detect a previous, resolved hepatitis B infection, or sometimes to guide and monitor treatment. Hepatitis B tests may be ordered when an individual has signs and symptoms associated with acute hepatitis to determine if they are due to infection with HBV. Some of these include:

- Fever
- Joint pain
- Fatigue
- Loss of appetite
- Nausea, vomiting
- Pale stools
- Jaundice
- Abdominal pain
- Dark urine

Hepatitis B tests may be done as a follow-up when routine tests result such as ALT and/or AST are elevated.

How the Test Is Done

Hepatitis testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Hepatitis B tests can be developed individually but are often developed with some combination, depending on the reason for testing. Test results are typically evaluated together. Sometimes the significance of one result depends on the result of another test. However, not all tests are done for all people.
The table below summarizes possible interpretations of some common patterns of results.

Hep B surface antigen (HBsAg)	Hep B surface antibody (Anti-HBs)	Hep B core antibody Total (Anti-HBc IgG+IgM)	Hep B core antibody (Anti-HBc IgM)	Possible Interpretation / Stage of Infection
Negative	Negative	Negative	Negative	No active or prior infection; not immune — may be a good candidate for the vaccine; possibly in the incubation stage
Negative	Positive	Negative	Not performed	Immunity due to vaccination
Negative	Positive	Positive	Not performed	The infection resolved; the virus could reactivate if the immune system suppressed
Positive	Negative	Positive or Negative	Positive	Acute infection, usually with symptoms; contagious; could also be a flare of chronic infection
Negative	Negative	Positive	Positive	Acute infection is resolving (convalescent)
Positive	Negative	Positive	Negative	Usually indicates an active chronic infection (liver damage likely)
Positive	Negative	Positive	Negative	Chronic infection but a low risk of liver damage — carrier state

Chapter 6: Pregnancy and Genetic Testing

Antisperm Antibody Test

Test Overview

An antisperm antibody test looks for special proteins (antibodies) that fight against a man's sperm in blood, vaginal fluids, or semen. The test uses a sample of sperm and adds a substance that binds only to the affected sperm.
It is done as a blood test in females and as a sperm test in males. The antibodies can damage or destroy sperm, thereby causing infertility.
Antisperm antibodies can be made in the body of a man in the following cases:

- When the testicles are injured after surgery (such as a biopsy or vasectomy)
- After a vasectomy
- After a prostate gland infection
- Testicular cancer

Antisperm antibodies can be made in the body of the woman when such a woman has an allergic reaction to her partner's semen.

Why the Test Is Done

- The test is done to diagnose and analyze the causes of infertility.
- It is also done to analyze the health of the reproductive organs.

How the Test Is Done

It is done as a blood test in females while a sperm sample is collected from males.

Results

Normal range	00 to 60 U/ml
Abnormal range	Above 60 U/ml

Alpha-Fetoprotein (AFP)

Test Overview

An AFP test measures the level of AFP in pregnant women during the second trimester of pregnancy. An AFP blood test is done to check a developing fetus for the risk of birth defects and genetic disorders, Down syndrome, or such as neural tube defects. Too much or too little AFP in a mother's blood can be a sign of a birth defect or other condition.
These include:

- A neural tube defect, a serious condition that causes abnormal development of a developing baby's brain and/or spine
- Twins or multiple births, because more than one baby is producing AFP
- Down syndrome, a genetic disorder that causes intellectual disabilities and developmental delays
- Miscalculation of the due date because AFP levels change during pregnancy

Why the Test Is Done

The test may be done if the individual:

- Has a family history of birth defects
- Is aged 35 years or older
- Has diabetes

How the Test Is Done

AFP testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal result	10 nanograms per milliliter of blood

Follicle-Stimulating Hormone (FSH)

Test Overview

An FSH test is a simple blood test that measures the level of FSH found in the blood. A medical practitioner will order an FSH test to find the underlying cause of symptoms affecting the reproductive system.

Why the Test Is Done

FSH test for women:

In women, the most common reasons for an FSH test include:

- Assessing infertility problems
- Assessing irregular menstrual cycles
- Diagnosing disorders of the pituitary gland or diseases involving the ovaries

FSH test for men

In men, an FSH test may be done to:

- Evaluate a low sperm count
- Assess hypogonadism or gonadal failure
- Assess testicular dysfunction

FSH test for children

An FSH test can be used to determine if a child is developing early puberty. An FSH test can also be used to determine if a child is developing delayed puberty. This occurs when sexual characteristics or organs do not develop when they should.

How the Test Is Done

FSH testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal FSH levels will differ, depending on a person's age and sex.

Normal Result

Male:

Before puberty	0 to 5.0 mIU/mL (0 to 5.0 IU/L)
During puberty	0.3 to 10.0 mIU/mL (0.3 to 10.0 IU/L)
Adult	1.5 to 12.4 mIU/mL (1.5 to 12.4 IU/L)

Female:

Before puberty	0 to 4.0 mIU/mL (0 to 4.0 IU/L)
During puberty	0.3 to 10.0 mIU/mL (0.3 to 10.0 IU/L)
Women who are still menstruating	4.7 to 21.5 mIU/mL (4.5 to 21.5 IU/L)
After menopause	25.8 to 134.8 mIU/mL (25.8 to 134.8 IU/L)

Abnormal Result

High FSH levels in men may mean the testicles are not functioning correctly due to:

- Advancing age (male menopause)

- Problems with genes, such as Klinefelter syndrome
- Treatment with hormones
- Damage to testicles caused by alcohol abuse, chemotherapy, or radiation
- Certain tumors in the pituitary gland

Low FSH levels in men may mean parts of the brain (the pituitary gland or hypothalamus) do not produce normal amounts of some or all of its hormones.
High FSH levels in women may be present:

- During or after menopause, including premature menopause
- Due to certain types of tumor in the pituitary gland
- When receiving hormone therapy
- Due to Turner syndrome

Low FSH levels in women may be present due to:

- Being very underweight or having had recent rapid weight loss
- Not producing eggs (not ovulating)
- Pregnancy
- Parts of the brain (the pituitary gland or hypothalamus) not producing normal amounts of some or all of its hormones

High FSH levels in boys or girls may mean that puberty is about to start.

Human Chorionic Gonadotropin (HCG)

Test Overview

The human chorionic gonadotropin (HCG) blood test measures the level of HCG hormone present in the blood.

Why the Test Is Done

The HCG blood test is performed to:

- Confirm pregnancy
- Screen for Down syndrome
- Diagnose an abnormal pregnancy, such as an ectopic pregnancy
- Diagnose a potential miscarriage
- Determine the approximate age of the fetus

How the Test Is Done

HCG testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

These levels are measured in milli-international units of HCG hormone per milliliter of blood (mIU/mL).
The table below shows the normal HCG levels during pregnancy for each week from the last menstrual period of the individual being tested.

A week from last menstrual period	**Normal HCG levels (mIU/mL)**
4	0 – 750
5	200 – 7,000
6	200 – 32,000
7	3000 – 160,000
8 – 12	32,000 – 210,000
13 – 16	9,000 – 210,000
16 – 29	1,400 – 53,000
29 – 41	940 – 60,000

For non-pregnant women:

Normal HCG levels	Less than 10.0 mIU/mL

Abnormal Result

Levels of HCG that are lower than normal could mean:

- A miscalculation of pregnancy dating
- A possible miscarriage or blighted ovum
- An ectopic pregnancy

Levels of HCG that are higher than normal could mean:

- A miscalculation of pregnancy dating
- A molar pregnancy, which is when an abnormal mass forms inside the uterus after fertilization instead of a normal embryo
- Multiple pregnancies, such as twins or triplets

Inhibin A

Test Overview

Inhibin A test is a basic blood test that measures the level of Inhibin A in the blood. It is used in pregnant women who are suspected of carrying a fetus with Down syndrome. The Inhibin A test is also used for the diagnosis of Granulosa cell tumors and Mucinous Epithelial Ovarian Tumor.

How the Test Is Done

Inhibin testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

Normal Result

Men	< 2pg/ml.
Premenopausal women	< 97.5 pg/ml
Postmenopausal women	< 2.1 pg/ml

Prolactin Level Test

Test Overview

A prolactin level test is done to check the level of prolactin in the blood.

Why the Test Is Done

In Women:
Women with symptoms of a prolactinoma may need to be tested. Prolactinoma is a non-cancerous tumor of the pituitary gland that produces high levels of prolactin.Symptoms of prolactinoma in women include:

- Unexplained headaches
- Galactorrhea, or lactation outside of childbirth or nursing
- Abnormal growth of body and facial hair
- Pain or discomfort during sex
- Visual impairment
- Abnormal acne

In addition, the prolactin test may be done if an individual is having fertility problems or irregular periods. The test can also rule out other pituitary gland or hypothalamus problems.
In Men:
Men may need the test if they display symptoms of prolactinoma. Symptoms of prolactinoma in

men include:

- Unexplained headaches
- Reduced sex drive or fertility problems
- Visual impairment
- Erectile dysfunction
- Abnormal lack of body and facial hair

The test may also be used to:

- Investigate testicular dysfunction or erectile dysfunction
- Rule out problems with the pituitary gland or hypothalamus

How the Test Is Done

Prolactin testing requires a blood sample. Hence, the health professional will take a blood sample, and then the sample will be sent to the lab for analysis.

Results

These levels are measured in (ng/mL = nanograms per milliliter).

Normal Result

Male	< 15 ng/mL
Pregnant female	34 to 386 ng/mL
Non-pregnant female	< 25 ng/mL

Chapter 7: Miscellaneous

Hematology-Oncology

Hematology-oncology refers to the combined medical practice of hematology (the study of the blood's physiology) and oncology (the study of cancer). This type of medical diagnoses and treats cancerous blood disorders and cancers and manages symptoms of these diseases and resultant tumors (if present). Hematology-oncology tests include tests on the blood, blood proteins, and blood-producing organs. These tests can evaluate a variety of blood conditions, including infection, anemia, inflammation, hemophilia, blood-clotting disorders, leukemia, and the body's response to chemotherapy treatments. In many cases, the results of a blood test can give an accurate assessment of body conditions and how internal or external influences may affect a patient's health.
Common hematology-oncology tests include:

White Blood Cells

White blood cells defend the body against infections and other foreign bodies.
Normal range:

- 4,500 to 11,000 cells per microliter (cells/mcL)

A high-level reading can be due to:

- Leukemia, infections, cigarette smoking, inflammatory diseases, severe physical or mental stress, tissue damage.

A low-level reading can be due to:

- Severe bacterial infections, autoimmune disorders, bone marrow deficiencies, viral diseases, spleen problems, radiation therapy, liver problems.

Red Blood Cells

The red blood cells' primary function is to carry oxygen from the lungs towards the body tissues and carry carbon dioxide away from those body tissues to the lungs.
Normal range:

Men	4.5 million to 5.9 million cells/mcL
Women	4.1 million to 5.1 million cells/mcL

A high-level reading can be due to:

- Pulmonary fibrosis, cigarette smoking, congenital heart disease, renal cell carcinoma, polycythemia vera, dehydration.

A low-level reading can be due to:

- Malnutrition, bleeding, anemia, overhydration, hemolysis, erythropoietin deficiency, leukemia, multiple myeloma, porphyria, thalassemia, sickle cell anemia.

Hemoglobin

Hemoglobin is the protein component of red blood cells. It makes the blood look bright red as it is made with iron.

Normal range:

Men	14 to 17.5 grams per deciliter (gm/dL)
Women	12.3 to 15.3 gm/dL

A high-level reading can be due to:

- Dehydration, cigarette smoking, polycythemia vera, tumors, erythropoietin abuse, lung diseases, blood doping.

A low-level reading can be due to:

- Blood loss, nutritional deficiencies, renal problems, sickle cell anemia, bone marrow suppression, lead poisoning, Hodgkin's lymphoma, leukemia.

Hematocrit

Hematocrit reflects the volume percentage of red blood cells in the whole blood.
Determining hematocrit is helpful in diagnosing and assessing blood diseases, nutritional deficiencies, and hydration status.

Normal range:

Male	41% – 50%
Female	36% – 44%
Children	36% – 40%
Newborn	55% – 68%

A high-level reading can be due to:

- Cigarette smoking, polycythemia vera, tumors, erythropoietin abuse, lung diseases, blood doping, dehydration, hypoxia, erythrocytosis, cor pulmonale.

A low-level reading can be due to:

- Lead poisoning, overhydration, nutritional deficiencies, chemotherapy treatment, blood loss, bone marrow suppression, leukemia, Hodgkin's lymphoma.

Platelets

Determining platelet count is vital in assessing patients for tendencies of bleeding and

thrombosis.
Normal range:

- 150,000 to 450,000 platelets/mcL

A high-level reading can be due to:

- Inflammation, allergic reactions, polycythemia vera, recent spleen removal, chronic myelogenous leukemia, cancer, secondary thrombocytosis.

A low-level reading can be due to:

- Aplastic anemia, leukemia, alcoholism, vitamin B12, and folic acid deficiency, viral infection, systemic lupus erythematosus, hemolytic uremic condition, HELLP syndrome, disseminated intravascular coagulopathy, vasculitis, splenic sequestration, cirrhosis, sepsis.

Immunology

There are numerous immunological tests for different medical conditions and purposes – for instance, to test for an allergy, to screen for bowel cancer, or to find out if a woman is pregnant. Immunology tests can be used to detect certain substances or pathogens (germs) in the body. Things that can be detected are viruses, hormones, or the blood pigment, hemoglobin. The tests take advantage of the body's immune system; that is, to fight off germs or foreign substances, the immune system produces numerous antibodies. Antibodies are simply proteins that can bind to a specific germ or substance. They "capture" germs or substances, neutralize them and attract other immune cells. Thus, immunoassays used in laboratories are done by producing artificial antibodies that "match" exactly the substance or germ in question. When these antibodies come into contact with a sample of blood, feces, or urine , they bind to the corresponding substance or germ, if present in the sample. This reaction indicates that the germ or substance is present.
Immunological tests are widely used. Their areas of application include:

Bowel Cancer Screening

- This test looks for the blood pigment hemoglobin, a sign of blood in the stool. Blood in the stool can be caused by various things, such as hemorrhoids, polyps, or even bowel cancer.

Diagnosing Heart Attacks and Thrombosis

- Shortly after a heart attack or if someone has thrombosis, higher levels of a certain protein are found in the blood. These can be detected using an immunological test.

Allergy Tests

- To detect antibodies against allergy-triggering substances like grass pollen or certain foods.

Detecting Germs Causing an Infection

If you think someone has bacterial tonsillitis or scarlet fever, the test detects Streptococcus bacteria. In the case of Lyme disease following a tick bite, there are tests that can detect the Borrelia bacteria that causes it, and there are tests that can detect antibodies to the Borrelia bacteria. Immunologic tests can also be used to detect viruses. Some examples are hepatitis C, HIV, or HPV viruses. Pregnant women can have a blood test to find out if they are protected (immune) from toxoplasmosis.

Pregnancy Test

- Women can use this rapid test to find out whether their urine contains the "pregnancy hormone" beta-HCG.

Rapid Tests for Drugs and Medication

- Immunological tests can also be used to look for recreational drugs such as cannabis, ecstasy, and cocaine. Medical drugs that affect the central nervous system can also be detected in this way. These include sleeping pills (benzodiazepines), amphetamines, and morphine.

Determining Blood Group

- When blood transfusions are done, the person donating the blood and the person receiving the blood must have the same blood group. Immunological tests can be used to determine the blood groups before a blood transfusion.

Urine Test

- If sugar, blood, proteins, or inflammatory cells are found in urine using this rapid test, it could be a sign of diabetes, a urinary tract infection, or kidney damage.

Gastrointestinal System

In order to reach a diagnosis for digestive disorders, some patients need to undergo extensive diagnostic evaluation. This may include lab tests, imaging tests, and/or endoscopic procedures. These tests may include any, or a combination of, the following:

Lab tests

Stool Culture

- A stool culture is meant to check for abnormal bacteria in the digestive tract that can cause diarrhea and other problems. A small stool sample is collected and sent

to the lab. In 2 to 3 days, the test will detect if abnormal bacteria are present.

Fecal Occult Blood Test

- A fecal occult blood test checks for hidden (occult) blood in the stool. It involves placing a very small amount of stool on a special card. The stool is then tested in the healthcare provider's office or sent to a lab.

Imaging Tests

Barium Beefsteak Meal

During this test, the patient eats a meal containing barium (i.e., a metallic, chalky liquid used to coat the inside of organs so that they show up on an x-ray). This allows the radiologist to observe the stomach as it digests the meal. The time it takes for the barium meal to be digested and leave the stomach gives the doctor an idea of how well the stomach is working and helps find emptying problems that may not show up on the liquid barium X-ray.

Colorectal Transit Study

- This test shows how well food moves through the colon—the patient swallows' capsules containing small markers that are visible on X-ray. The patient follows a high-fiber diet during the course of the test. The movement of the markers through the colon is monitored with abdominal X-rays taken several times 3 to 7 days after the capsule is swallowed.

Lower GI (Gastrointestinal) Series (Also Called Barium Enema)

- A lower GI series is a test that examines the rectum, the large intestine, and the lower part of the small intestine. Barium is given into the rectum as an enema. An X-ray of the abdomen shows strictures (narrowed areas), obstructions (blockages), and other problems.

Defecography

- Defecography is an X-ray of the anorectal area that evaluates completeness of stool elimination, identifies anorectal abnormalities, and evaluates rectal muscle contractions and relaxation. During the exam, the patient's rectum is filled with a soft paste that is the same consistency as feces. The patient then sits on a toilet positioned inside an X-ray machine and squeezes and relaxes the anus to expel the solution. The radiologist studies the X-rays to determine if anorectal problems happened while the patient was emptying the paste from the rectum.

Endoscopic Procedures

Sigmoidoscopy

- A sigmoidoscopy is a diagnostic procedure that allows a doctor to examine the inside of a portion of the large intestine and is useful in identifying the causes of diarrhea, constipation, abdominal pain, abnormal growths, and bleeding. A short, lighted, flexible tube, called a sigmoidoscope, is inserted into the intestine through the rectum. The device blows air into the intestine to inflate it and make it easier to visualize the inside.

Colonoscopy

- A colonoscopy is a procedure that allows a doctor to view the entire length of the large intestine (colon). It can often help identify abnormal growths, bleeding, ulcers, and inflamed tissue. It involves inserting a colonoscope: a long, flexible, lightweight tube through the rectum into the colon. The colonoscope allows the doctor to view the lining of the colon, remove tissue for further examination and possibly treat some problems that are discovered.

Pulmonary Function Test

Pulmonary function tests (PFTs) are a group of tests that measure how well the respiratory system works – the lungs in particular. These tests check how well an individual is able to breathe and how effectively their lungs are able to bring oxygen to the rest of their body.

Spirometry

- Spirometry is the most important function test. Basically, it measures the amount of air an individual breathes in and out. This allows a differentiation between restrictive and obstructive respiratory diseases.

Plethysmography Test

- A plethysmography test measures the volume of gas in the lungs, known as lung volume.

Diffusing Capacity

- The diffusing capacity of the lung for carbon monoxide (also known as transfer factor), which is usually performed as a single-breath test, measures the overall gas-exchange function of the lung.

Blood Gas Analysis

- Arterial blood gas (ABG) measurement is used to determine the arterial oxygen tension (PaO_2) and the arterial carbon dioxide tension ($PaCO_2$). ABG

measurement allows the diagnosis of hypoxemia (decreased PaO_2) and hypercapnia (increased $PaCO_2$).

Respiratory Muscle Function Measurement

- Respiratory muscle function is commonly assessed by measuring maximal pressures generated at the mouth during maximal inspiratory and expiratory efforts against an occluded airway.

Central Nervous System

Evaluating and diagnosing damage to the nervous system can be very complicated as many of the same symptoms occur in different combinations among the different disorders. To further complicate the diagnostic process, many disorders do not have definitive causes, markers, or tests.
Neurological tests include:

Computed Tomography Scan (Also Called a CT or CAT Scan)

- A diagnostic imaging procedure that uses a combination of X-rays and computer technology to produce horizontal, or axial, images (often called slices) of the body. A CT scan shows detailed images of any part of the body, including the brain, bones, muscles, fat, and organs. CT scans are more detailed than general X-rays.

Electroencephalogram (EEG)

- This procedure records the brain's continuous electrical activity by means of electrodes attached to the scalp.

Magnetic Resonance Imaging (MRI)

- A diagnostic procedure that uses a combination of large magnets, radio frequencies, and a computer to produce detailed images of organs and structures within the body.

Electrodiagnostic Tests (Electromyography and Nerve Conduction Velocity)

- These tests evaluate and diagnose disorders of nerves, motor neurons, and muscles. Electrodes are inserted into the muscle or placed on the skin over a nerve, and electrical activity and muscle response are recorded.

Positron Emission Tomography (PET) Scan

- A computer-based imaging technique that provides a picture of the brain's activity

rather than its structure by measuring levels with an injected tracer molecule, most often glucose.

Arteriogram (Also Called Angiogram)

- This procedure provides an image of arteries and/or veins going to and through the brain. CT angiography, a newer and less invasive technique, is sometimes used.

Cerebral Spinal Fluid Analysis (also called Spinal Tap or Lumbar Puncture)

- This procedure is used to make an evaluation or diagnosis by examining the fluid withdrawn from the thecal sac, the sac of fluid positioned below where the spinal column has come to an end.

Evoked Potentials

- This procedure records the brain's electrical response to visual, auditory, and sensory stimuli.

Myelogram

- This procedure uses dye injected into the spinal canal to make the structure clearly visible on X-rays. Though once common, it is rarely used nowadays.

neurosonography

- This procedure uses ultra-high-frequency sound waves that enable the medical practitioner to evaluate structures of the nervous system, including the brain, spinal cord, and other structures.

Musculoskeletal System

Musculoskeletal disorders (MSDs) are conditions that can affect your muscles, bones, and joints. MSDs include:

- Tendinitis
- Carpal tunnel syndrome
- Osteoarthritis
- Rheumatoid arthritis (RA)
- Fibromyalgia
- Bone fractures

Laboratory tests are often helpful in making the diagnosis of a musculoskeletal disorder.

Different laboratory tests can be conducted to diagnose MSDs, for instance:

- Erythrocyte sedimentation rate (ESR) is a test that measures how quickly red blood cells settle to the bottom of a tube containing blood. ESR increases when inflammation is present. However, because inflammation occurs in so many conditions, ESR alone does not establish a diagnosis.
- The level of creatine kinase (a normal muscle enzyme that leaks out and is released into the bloodstream when a muscle is damaged) may also be tested. Levels of creatine kinase are increased when there is the widespread, ongoing destruction of muscle.
- In rheumatoid arthritis, a blood test to identify rheumatoid factor or anti-cyclic citrullinated peptide (anti-CCP) antibody is helpful in making the diagnosis.
- In systemic lupus erythematosus (SLE or lupus), blood tests to identify autoimmune antibodies (autoantibodies), such as antinuclear antibodies and antibodies to double-stranded deoxyribonucleic acid (DNA), help in making the diagnosis.
- A blood test can be done to identify people who have a certain gene (HLA-B27). People who have this gene are at increased risk of developing spondyloarthritis – a group of disorders that can cause inflammation of the back and other joints as well as other symptoms, such as eye pain and redness, and rashes.

Certain laboratory tests are also often useful to help monitor treatment progress. Example, ESR may be useful to help monitor treatment progress in rheumatoid arthritis or polymyalgia rheumatica. A decrease in ESR suggests that treatment is working to reduce inflammation.

Serum Electrolytes

Electrolytes are electrically charged minerals that help control the number of fluids and the balance of acids and bases in the body. They also help control muscle and nerve activity, heart rhythm, and other important functions. An electrolyte panel is often part of a basic metabolic panel.

A serum electrolyte test is a blood test that measures levels of the body's main electrolytes, which are:

- **Sodium**: This electrolyte helps control the amount of fluid in the body. It also helps the nerves and muscles work properly.
- **Chloride**: This electrolyte also helps control the amount of fluid in the body. In addition, it helps maintain healthy blood volume and blood pressure.
- **Potassium**: This electrolyte helps the heart and muscles work properly.
- **Bicarbonate**: This electrolyte helps maintain the body's acid and base balance. It also plays an important role in moving carbon dioxide through the bloodstream.

Abnormal levels in any of these electrolytes can be a sign of a serious health problem, including high blood pressure and kidney disease.

Vitamins and Trace Elements

Vitamins

A healthy balanced diet containing a variety of foods should provide all the vitamins the body needs to work properly.
There are 2 types of vitamins, fat-soluble and water-soluble.

Fat-Soluble Vitamins

Fat-soluble vitamins are mainly found in foods that are high in natural fat - such as dairy, eggs, and oily fish.
An individual doesn’t need to eat these types of food every day to get enough of these vitamins. Every time they eat these foods, their body stores them in their liver and body fat for future use.
Fat-soluble vitamins include:

- Vitamin A
- Vitamin D
- Vitamin E
- Vitamin K

Water-Soluble Vitamins

Unlike fat-soluble vitamins, an individual needs to consume water-soluble vitamins more often as the body can't store these for future use. The body also gets rid of any excess whenever urine is passed out.
Water-soluble vitamins include:

- Folic acid
- Vitamin C
- Vitamin B

They're found in:

- Dairy foods
- Fruit and vegetables
- Grains

Trace Elements

Trace elements are also essential nutrients, however, they are needed in smaller amounts than vitamins. Essential trace elements include iodine and zinc. However, there are many more elements the body needs to function, including:

- Manganese
- Nickel

- Boron
- Chromium
- Cobalt
- Molybdenum
- Selenium
- Copper

Drugs and Toxins

Drug toxicity occurs when a person has accumulated too much of a drug in their bloodstream, leading to adverse effects on the body. Drug toxicity may occur when the dose is given too high, or the liver or kidneys are unable to remove the drug from the bloodstream, allowing it to accumulate in the body.

Acute toxicity is easily diagnosed, as the symptoms will follow the one-time administration of medication. Blood tests can also be used to screen for levels of the medication in the person's bloodstream. Chronic toxicity, on the other hand, is harder to diagnose. Stopping the medication and then tackling it later on is one method of testing whether the symptoms are caused by the medication. This method can be problematic. However, it is recommended if the medication is essential and doesn't have an equivalent substitute.

There are several ways in which drug toxicity may be treated. If the toxicity is the result of an acute overdose, then a person may undergo stomach pumping to remove drugs that have not yet been absorbed. Activated charcoal may also be administered to bind the drugs and prevent them from being absorbed into the blood; instead, it is eliminated from the body through the stool.

Chapter 8: Test Your Knowledge

Interpret whether the following test results are normal or abnormal.

Question 1:

A hemoglobin test result for a male patient shows 4 g/dL. How do you interpret this result?

Question 2:

A hematocrit test result for a female patient shows 84%. How do you interpret this result?

Question 3:

A sodium blood test result shows 63 mEq/L. How do you interpret this result?

Question 4:

A phosphorus test result for a child shows a reference range of 4.5 mg/dL. How do you interpret this result?

Question 5:

A CPK test result for a male shows 450 U/L. How do you interpret this result?

Question 6:

A BNP test result for a 30-year-old woman shows 60 pg/ml. How do you interpret this result?

Question 7:

A prolactin blood test result for a pregnant lady shows 409 ng/mL. How do you interpret this test result?

Question 8:

A potassium blood test result for a new-born baby shows 4.6 mEq. How do you interpret this result?

Question 9:

A magnesium blood test result for a child shows 1.9 mg/dL. How do you interpret this test?

Question 10:

A troponin blood test result for an individual shows 0.10 ng/mL. How do you interpret this result?

Chapter 9: Answers to Exercises

Here are the answers to the questions from the previous chapter.
Question 1: The test result is abnormally low.
Question 2: The test result is abnormally high.
Question 3: The test result is abnormally low.
Question 4: The test result is normal.
Question 5: The test result is abnormally high.
Question 6: The test result is normal.
Question 7: The test result is abnormally high.
Question 8: The test result is normal.
Question 9: The test result is normal.
Question 10: The test result is abnormally high.

Conclusion

Getting conversant with laboratory values and interpreting them can be daunting, especially to new nurses. There's always the anxiety of messing things up and not being able to meet the patient's health needs. However, with the contents of this book, you should be able to interpret lab values easily and correctly when you next come across them. It is recommended that you read and re-read the contents of this book until you feel extremely comfortable with the interpretations of different lab values.