Cardiac Output

Chapter 98

INTRODUCTION

Cardiac output is the amount of blood pumped from each ventricle. Usually, it refers to left ventricular output through aorta. Cardiac output is the most important factor in cardiovascular system, because rate of blood flow through different parts of the body depends upon cardiac output.

DEFINITIONS AND NORMAL VALUES

Usually, cardiac output is expressed in three ways:

1. Stroke volume
2. Minute volume
3. Cardiac index.

However, in routine clinical practice, cardiac output refers to minute volume.

STROKE VOLUME

Stroke volume is the amount of blood pumped out by each ventricle during each beat.

Normal value: 70 mL (60 to 80 mL) when the heart rate is normal (72/minute).

MINUTE VOLUME

Minute volume is the amount of blood pumped out by each ventricle in one minute. It is the product of stroke volume and heart rate:

Minute volume = Stroke volume × Heart rate

Normal value: 5 L/ventricle/minute.

CARDIAC INDEX

Cardiac index is the minute volume expressed in relation to square meter of body surface area. It is defined as the amount of blood pumped out per ventricle/minute/square meter of the body surface area.

Normal value: 2.8 ± 0.3 L/square meter of body surface area/minute (in an adult with average body surface area of 1.734 square meter and normal minute volume of 5 L/minute).

EJECTION FRACTION

Ejection fraction is the fraction of end diastolic volume that is ejected out by each ventricle. Normal ejection fraction is 60% to 65%. Refer Chapter 91 for details.

CARDIAC RESERVE

Cardiac reserve is the maximum amount of blood that can be pumped out by heart above the normal value. Cardiac reserve plays an important role in increasing the cardiac output during the conditions like exercise. It is essential to withstand the stress of exercise.

Cardiac reserve is usually expressed in percentage. In a normal young healthy adult, the cardiac reserve is 300% to 400%. In old age, it is about 200% to 250%. It increases to 500% to 600% in athletes. In cardiac diseases, the cardiac reserve is minimum or nil.

VARIATIONS IN CARDIAC OUTPUT

PHYSIOLOGICAL VARIATIONS

1. *Age:* In children, cardiac output is less because of less blood volume. Cardiac index is more than that in adults because of less body surface area.
2. *Sex:* In females, cardiac output is less than in males because of less blood volume. Cardiac index is more than in males, because of less body surface area.
3. *Body build:* Greater the body build, more is the cardiac output.
4. *Diurnal variation:* Cardiac output is low in early morning and increases in day time. It depends upon the basal conditions of the individuals.
5. *Environmental temperature:* Moderate change in temperature does not affect cardiac output. Increase in temperature above 30°C raises card[illegible]
6. *Emotional conditions:* Anxiety, apprehension and excitement increases cardiac output about 50% to 100% through the release of catecholamines, which increase the heart rate and force of contraction.
7. *After meals:* During the first one hour after taking meals, cardiac output increases.
8. *Exercise:* Cardiac output increases during exercise because of increase in heart rate and force of contraction.
9. *High altitude:* In high altitude, the cardiac output increases because of increase in secretion of adrenaline. Adrenaline secretion is stimulated by hypoxia (lack of oxygen).
10. *Posture:* While changing from recumbent to upright position, the cardiac output decreases.
11. *Pregnancy:* During the later months of pregnancy, cardiac output increases by 40%.
12. *Sleep:* Cardiac output is slightly decreased or it is unaltered during sleep.

PATHOLOGICAL VARIATIONS

Increase in Cardiac Output

Cardiac output increases in the following conditions:

1. *Fever:* Due to increased oxidative processes
2. *Anemia:* Due to hypoxia
3. *Hyperthyroidism:* Due to increased basal metabolic rate.

Decrease in Cardiac Output

Cardiac output decreases in the following conditions:

1. *Hypothyroidism:* Due to decreased basal metabolic rate
2. *Atrial fibrillation:* Because of incomplete filling of ventricles
3. *Incomplete heart block with coronary sclerosis or myocardial degeneration:* Due to defective pumping action of the heart
4. *Congestive cardiac failure:* Because of weak contractions of heart
5. *Shock:* Due to poor pumping and circulation
6. *Hemorrhage:* Because of decreased blood volume.

DISTRIBUTION OF CARDIAC OUTPUT

The whole amount of blood pumped out by the right ventricle goes to lungs. But, the blood pumped by the left ventricle is distributed to different parts of the body.

Fraction of cardiac output distributed to a particular region or organ depends upon the metabolic activities of that region or organ.

Distribution of Blood Pumped out of Left Ventricle

Distribution of blood pumped out of left ventricle to different organs and the percentage of cardiac output are given in Table. 98.1. Heart, which pumps the blood to all other organs, receives the least amount of blood. Liver receives maximum amount of blood.

FACTORS MAINTAINING CARDIAC OUTPUT

Cardiac output is maintained (determined) by four factors:

1. Venous return
2. Force of contraction
3. Heart rate
4. Peripheral resistance.

1. VENOUS RETURN

Venous return is the amount of blood which is returned to heart from different parts of the body. When it increases, the ventricular filling and cardiac output are increased. Thus, cardiac output is **directly proportional** to venous return, provided the other factors (force of contraction, heart rate and peripheral resistance) remain constant.

Venous return in turn, depends upon five factors:

i. Respiratory pump
ii. Muscle pump
iii. Gravity
iv. Venous pressure
v. Sympathetic tone.

i. *Respiratory Pump*

Respiratory pump is the respiratory activity that helps the return of blood, to heart during inspiration. It is also called **abdominothoracic pump.** During inspiration, thoracic cavity expands and makes the intrathoracic pressure more negative. It increases the diameter of inferior vena cava, resulting in increased venous return.

At the same time, descent of diaphragm increases the intra-abdominal pressure, which compresses abdominal veins and pushes the blood upward towards the heart and thereby the venous return is increased (Fig. 98.1).

Respiratory pump is much stronger in forced respiration and in severe muscular exercise.

TABLE 98.1: Distribution of blood pumped out of left ventricle

Organ	Amount of blood (mL/ minute)	Percentage
Liver	1,500	30
Kidney	1,300	26
Skeletal muscles	900	18
Brain	800	16
Skin, bone and GI tract	300	6
Heart	200	4
Total	5,000	100

ii. *Muscle Pump*

Muscle pump is the muscular activity that helps in return of the blood to heart. During muscular activities, the veins are compressed or squeezed. Due to the presence of valves in veins, during compression the blood is moved towards the heart (Fig. 98.2). When muscular activity increases, the venous return is more.

When the skeletal muscles contract, the vein located in between the muscles is compressed. Valve of the vein

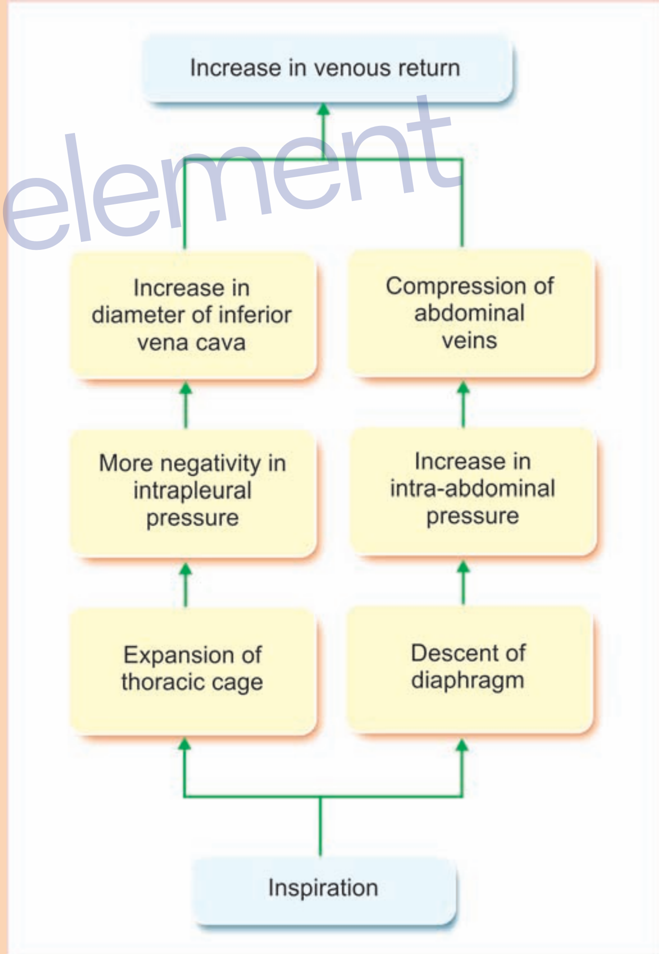

FIGURE 98.1: Effect of respiratory pump on venous return

proximal to the contracting muscles (Fig. 98.2 A) is opened and the blood is propelled towards the heart. Valve of the vein distal to the muscles is closed by the back flow of blood.

During relaxation of the muscles (Fig. 98.2 B), the valve proximal to muscles closes and prevents the back flow of blood. The valve distal to the muscles opens and allows the blood to flow upwards.

iii. *Gravity*

Gravitational force reduces the venous return. When a person stands for a long period, gravity causes pooling of blood in the legs, which is called **venous pooling.** Because of venous pooling, the amount of blood returning to heart decreases.

iv. *Venous Pressure*

Venous pressure also affects the venous return. Pressure in the venules is 12 to 18 mm Hg. In the smaller and larger veins, the pressure gradually decreases. In the great veins, i.e. inferior vena cava and superior vena cava, the pressure falls to about 5.5 mm Hg. At the junction of venae cavae and right atrium, it is about 4.6 mm Hg. Pressure in the right atrium is still low and it alters during cardiac action. It falls to zero during atrial diastole. This pressure gradient at every part of venous tree helps as a driving force for venous return.

v. *Sympathetic Tone*

Venous return is aided by sympathetic or vasomotor tone (Chapter 103), which causes constriction of venules. Venoconstriction pushes the blood towards heart.

■ 2. FORCE OF CONTRACTION

Cardiac output is **directly proportional** to the force of contraction, provided the other three factors remain constant. According to **Frank-Starling law,** force of contraction of heart is directly proportional to the initial length of muscle fibers, before the onset of contraction.

Force of contraction depends upon preload and afterload.

Preload

Preload is the stretching of the cardiac muscle fibers at the end of diastole, just before contraction. It is due to increase in ventricular pressure caused by filling of blood during diastole. Stretching of muscle fibers increases their length, which increases the force of contraction and cardiac output.

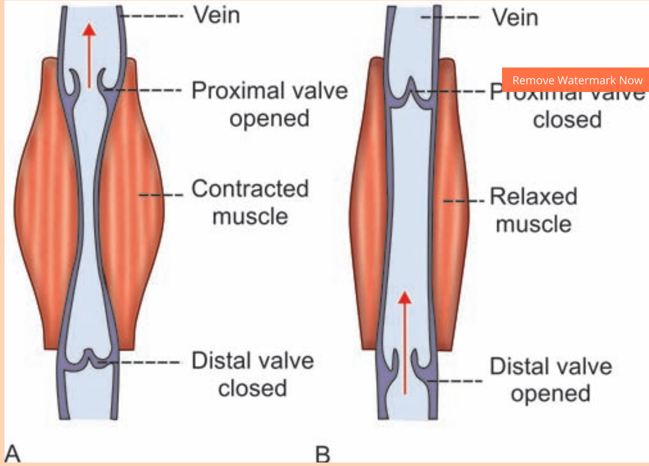

FIGURE 98.2: Mechanism of muscle pump. A. During contraction of the muscle; B. During relaxation of the muscle.

Thus, force of contraction of heart and cardiac output are **directly proportional** to preload.

Afterload

Afterload is the force against which ventricles must contract and eject the blood. Force is determined by the arterial pressure. At the end of isometric contraction period, semilunar valves are opened and blood is ejected into the aorta and pulmonary artery. So, the pressure increases in these two vessels. Now, the ventricles have to work against this pressure for further ejection. Thus, the afterload for left ventricle is determined by aortic pressure and afterload for right ventricular pressure is determined by pressure in pulmonary artery.

Force of contraction of heart and cardiac output are **inversely proportional** to afterload.

■ 3. HEART RATE

Cardiac output is **directly proportional** to heart rate provided, the other three factors remain constant. Moderate change in heart rate does not alter the cardiac output. If there is a marked increase in heart rate, cardiac output is increased.

If there is marked decrease in heart rate, cardiac output is decreased.

■ 4. PERIPHERAL RESISTANCE

Peripheral resistance is the resistance offered to blood flow at the peripheral blood vessels. Peripheral resistance is the resistance or load against which the heart has to pump the blood. So, the cardiac output is **inversely proportional** to peripheral resistance.

Resistance is offered at **arterioles** so, the arterioles are called **resistant vessels.** In the body, maximum peripheral resistance is offered at the **splanchnic region.** Other details of peripheral resistance are given in Chapter 102.

MEASUREMENT OF CARDIAC OUTPUT

Cardiac output is measured by direct methods and indirect methods. Direct methods are used only in animals. Indirect methods are used both in animals and human beings.

MEASUREMENT OF CARDIAC OUTPUT BY DIRECT METHODS

Direct methods used to measure cardiac output in animals:
1. By using cardiometer
2. By using flowmeter.

1. *By Using Cardiometer*

This is described in Chapter 91.

2. *By Using Flowmeter*

Mechanical flowmeter

Mechanical flowmeter is used to measure cardiac output or the amount of blood flow to any organ. It is used only in animals. It has an inlet, a measuring device in the middle and an outlet. Aorta or the artery entering any organ is cut. Inlet and outlet of the flowmeter are inserted into cut ends of the blood vessel. When the blood passes through the flowmeter, the measuring device determines the amount of blood flow (Fig. 99.1).

Electromagnetic flowmeter

Principle: Principle of this flowmeter is to develop an electromagnetic field by means of two coils of wire. If the coils are placed on either side of a blood vessel, the electromagnetic field is produced around the vessel. When blood flows through the vessel, there is an alteration in the electromagnetic field. By using appropriate electrodes, the changes in the magnetic field can be detected. By connecting electrodes to an electronic device, velocity of blood flow is determined on the basis of changes in the magnetic field. From the velocity of blood flow, the volume of blood flow is calculated.

Instrument: An **electromagnetic probe** is devised with the electromagnetic coils and the electrodes. The probe has a cleft and it is fixed in such a way that the intact blood vessel passes through the cleft. The probe almost encircles the blood vessel. The probe is connected to the electronic device to measure the volume of blood flow.

Advantage of this flowmeter is that the blood vessel need not be cut open.

Ultrasonic Doppler flowmeter

Principle: Ultrasound is the sound with very high frequency. It is very much beyond the audible range of human ears. The waves of the **ultrasound** are transmitted through a blood vessel. These sound waves are called **transmitted waves.** While passing through the blood vessels, the sound waves hit against the blood cells, particularly the red blood cells and are reflected back. Frequency of the **reflected waves** is different from that of the transmitted waves. This effect is called the **Doppler effect** (named after the discoverer **Johann Christian Doppler**). Alteration in the frequency of reflected waves depends upon the velocity of blood flowing through the blood vessel. By detecting the differences between frequencies of transmitted and reflected sound waves, the velocity of blood flow and then the volume of blood flow are determined.

Instrument: Ultrasonic device has piezoelectric crystals, which produce the **ultrasonic waves** and act as sensors to receive the reflected waves. This device is connected to an electronic equipment, which detects the difference between the frequencies of transmitted and reflected waves and thereby, determines the velocity of blood flow and the volume of blood flow.

Disadvantages of Direct Methods

i. Direct methods to measure cardiac output can be used only in animals
ii. Blood vessel has to be cut open at the risk of animal's life
iii. While using cardiometer, the size of the cardiometer must be suitable for the size of the heart
iv. While using mechanical flowmeter, diameter of inlet and the outlet of the flowmeter must be equivalent to the diameter of the blood vessel.

MEASUREMENT OF CARDIAC OUTPUT BY INDIRECT METHODS

Several methods are available to measure cardiac output. Each method has got its own advantages and disadvantages. Generally, the safe and accurate method is preferred. In view of safety, always non-invasive methods are preferred. The invasive method is also accepted provided, it gives accurate results. In addition to providing measurement of cardiac output, nowadays the methods are expected to provide other hemodynamic data and some useful information about the structure and movements of valves and chambers of the heart.

Invasive and Non-invasive Methods

Invasive method refers to a procedure which involves invasion or penetration of healthy tissues, organs or parts of the body, by means of perforation, puncture, incision, injection or catheterization. Non-invasive method means the procedure that does not involve invasion or penetration of tissues, organs or parts of the body.

Different Indirect Methods

Indirect methods used to measure cardiac output:

1. By using Fick principle
2. Indicator (dye) dilution technique
3. Thermodilution technique
4. Ultrasonic Doppler transducer technique
5. Doppler echocardiography
6. Ballistocardiography.

1. By Using Fick Principle

Adolph Fick described Fick principle in 1870. According to this principle, the amount of a substance taken up by an organ (or by the whole body) or given out in a unit of time is the product of amount of blood flowing through the organ and the arteriovenous difference of the substance across the organ.

$$\text{Amount of substance taken or given} = \text{Amount of blood flow/minute} \times \text{Arteriovenous difference}$$

For example,

Amount of blood flowing through lungs is 5,000 mL/minute

O_2 content in arterial blood = 20 mL/100 mL of blood

O_2 content in venous blood = 15 mL/100 mL of blood

$$\text{Amount of oxygen moved from lungs to blood} = \text{Amount of blood flow/minute} \times \text{Arteriovenous difference of } O_2$$

$$= 5{,}000 \times \frac{20 - 15}{100}$$

$$= 5{,}000 \times \frac{5}{100} = 250$$

Amount of oxygen moved from lungs to blood = 250 mL/minute

Modification of Fick principle to measure cardiac output

Fick principle is modified to measure the cardiac output or a part of cardiac output (amount of blood to an organ). Thus, cardiac output or the amount of blood flowing through an organ in a given unit of time is determined by the formula:

$$\text{Cardiac output} = \frac{\text{Amount of substance taken or given by the organ/minute}}{\text{Arteriovenous difference of the substance across the organ}}$$

By modifying Fick principle, cardiac output is measured in two ways:

i. By using oxygen consumption
ii. By using carbon dioxide given out.

Measurement of Cardiac Output by Using Oxygen Consumption

Fick principle is used to measure the cardiac output by determining the amount of oxygen consumed in the body in a given period of time and dividing this value by the arteriovenous difference across the lungs.

$$\text{Cardiac output} = \frac{O_2 \text{ consumed (in mL/minute)}}{\text{Arteriovenous } O_2 \text{ difference}}$$

Oxygen consumption: Amount of oxygen consumed is measured by using a **respirometer** or **BMR apparatus (Benedict Roth apparatus).**

Oxygen content in arterial blood: Blood is collected from any artery to determine the oxygen content in arterial blood. Oxygen content is determined by blood gas analysis.

Oxygen content in venous blood: Only mixed venous blood is used to determine the oxygen content of venous blood, since oxygen content is different in different veins. Mixed venous blood is collected from right atrium or pulmonary artery. It is done by introducing a **catheter** through basilar vein of forearm. Oxygen is determined from this blood by **blood gas analysis** (Fig. 98.3).

Calculation

For example, in a subject, the following data are obtained:

O_2 consumed (by lungs) = 250 mL/minute

O_2 content in arterial blood = 20 mL/100 mL of blood

O_2 content in venous blood = 15 mL/100 mL of blood

$$\text{Cardiac output} = \frac{O_2 \text{ consumed (in mL/minute)}}{\text{Arteriovenous } O_2 \text{ difference}}$$

$$= \frac{250}{5/100} = \frac{250 \times 100}{5}$$

$$= 5{,}000 \text{ mL/minute}$$

5 mL of oxygen is taken by 100 mL of blood while passing through the lungs. Thus, 250 mL of oxygen is taken by 5,000 mL of blood. Since cardiac output is equivalent to the amount of blood passing through pulmonary circulation, the cardiac output = 5 L/minute.

Measurement of Cardiac Output by Using Carbon Dioxide

Cardiac output is also measured by knowing the arteriovenous difference of carbon dioxide and amount of carbon dioxide given out (removed) by lungs (Fig. 98.4). Thus:

$$\text{Cardiac output} = \frac{CO_2 \text{ evolved (in mL/minute)}}{\text{Arteriovenous } CO_2 \text{ difference}}$$

Calculation

For example, in a subject

CO_2 removed by lungs = 200 mL/minute

CO_2 content in arterial blood = 56 mL/100 mL of blood

CO_2 content in venous blood = 60 mL/100 mL of blood

$$\text{Cardiac output} = \frac{200}{60 - 56 \text{ mL}/100 \text{ mL}}$$

$$= \frac{200 \times 100}{4}$$

$$= 5{,}000 \text{ mL} = 5 \text{ L/minute}$$

Since cardiac output is equal to the amount of blood passing through lungs (pulmonary circulation), the cardiac output = 5 L/minute.

Nitrous oxide is also used to measure cardiac output by applying Fick principle.

Advantage of measurement of cardiac output by Fick principle

The results are accurate.

Disadvantage

Fick principle is an invasive method and involves the insertion of catheter through subject vein.

2. Indicator (Dye) Dilution Method

Indicator dilution technique is described in detail in Chapter 6. Marker substance used to measure cardiac output is lithium chloride.

Advantage

The results are accurate.

Disadvantage

Indicator dilution method is an invasive method and involves injection of marker substance.

3. Thermodilution Technique

Cardiac output can also be measured by thermodilution technique or **thermal indicator method.** This method is the modified indicator dilution method. It is the popular method to measure cardiac output.

In this method, a known volume of cold sterile solution is injected into the right atrium via inferior vena

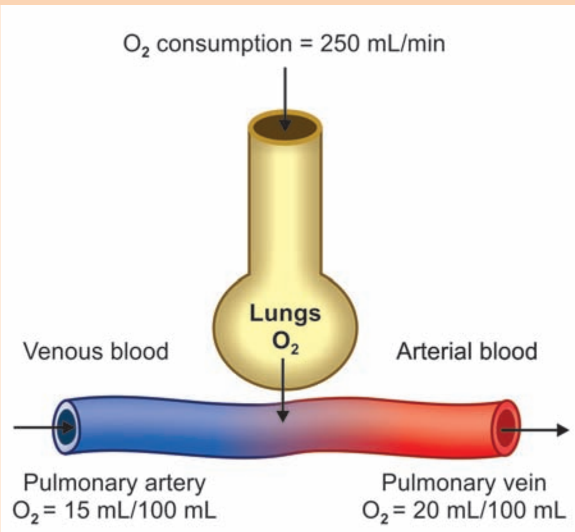

FIGURE 98.3: Oxygen consumption

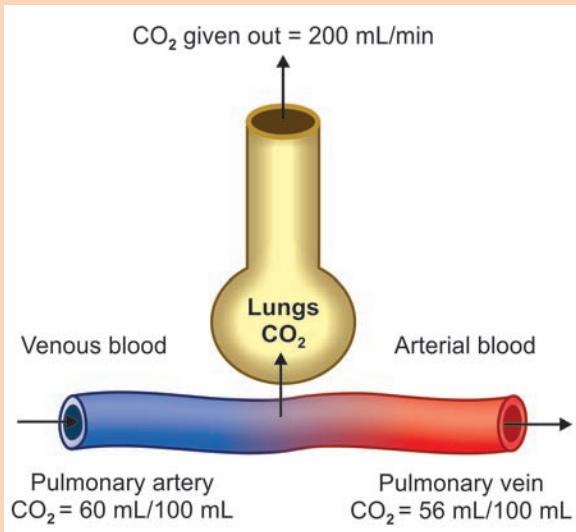

FIGURE 98.4: Carbon dioxide given out

cava by using a catheter. Cardiac output is measured by determining the resultant change in the blood temperature in pulmonary artery. For this purpose, two **thermistors (temperature transducers)** are used. One of them is placed in the inferior vena cava and the second one is placed in pulmonary artery. A pulmonary artery catheter is used to place the thermistors in their positions.

A known quantity of cold saline or cold dextrose solution is injected into inferior vena cava. Thermistors determine the temperature of blood entering the heart via inferior vena cava and temperature of blood leaving the heart via pulmonary artery. From the values of temperature, cardiac output is measured by applying indicator dilution technique.

Advantages

Results are accurate in this method. Even low cardiac output can be measured. Saline is also harmless. Catheter is also used to determine hemodynamic pressures and to collect mixed venous blood.

Disadvantage

Thermodilution technique is an invasive method and it requires catheterization.

Continuous cardiac output measurement catheter

Cardiac output can be measured continuously by using a modified pulmonary artery catheter called **continuous cardiac output measurement catheter** (CCO catheter). CCO catheter works on thermodilution principle. Instead of injecting cold saline, a heating filament which delivers heat directly to blood is used. The heating filament is fitted to the ventricular portion of the catheter. Cardiac output is measured as done in thermodilution technique. This method is commonly used in intensive care unit (ICU).

4. Esophageal Ultrasonic Doppler Transducer Technique

Esophageal ultrasonic doppler transducer technique involves insertion of a flexible probe into midthoracic part of esophagus. A pulse wave ultrasonic **Doppler transducer** is fixed at the tip of the probe. This transducer calculates the velocity of blood flow in descending aorta (refer ultrasonic Doppler flow meter for details). The diameter of aorta is determined by echocardiography (see below). Cardiac output is calculated by using the values of velocity of blood flow and diameter of aorta.

Advantages

The cardiac output can be measured continuously. This can be used during cardiac surgery.

Disadvantages

Esophageal ultrasonic doppler transducer is an invasive method and results are less accurate.

5. Doppler Echocardiography

Doppler echocardiography is a method for detecting the direction and velocity of moving blood within the heart. This is also a popular method to measure cardiac output.

Echocardiography is a **diagnostic procedure,** which uses the ultrasound waves (more than 20,000 Hz) to produce the image of the heart muscle. Ultrasound waves which reflect or echo off the heart can determine the size, shape, movement of the valves and chambers and the flow of blood through the heart.

During echocardiographic examination, the patient lies bare-chested on the examination table. A special gel is spread over the chest to help the transducer make good contact and slide smoothly over the skin. The transducer is a small hand operated device, which is attached to machine by a flexible cable. The transducer is placed against the chest. The transducer produces and directs ultrasound waves into the chest. Some of the waves get reflected (or echoed) back to the transducer. The reflection of sound waves depends upon the type of tissues and blood. The reflected sound waves are received by the transducer and translated into an image of the heart and displayed on a monitor or recorded on paper or tape.

Echocardiography may also show the abnormalities in functioning of heart valves or damage to the myocardium from an earlier heart attack.

When **Doppler principle** is applied in echocardiography, it enables the determination of direction, rate and other characteristics of blood flow. Doppler echocardiography is based upon the changes in frequency of the reflected sound waves from red blood cells (refer ultrasonic Doppler flow meter for details).

By Doppler echocardiography, the velocity of blood flow through aortic valve is determined. The diameter of the aorta is determined by simple echocardiography. From these values, cardiac output is calculated.

Advantage

Doppler echocardiography is a non-invasive technique. It also provides other useful information about the structures and movements of valves and chambers of heart.

Disadvantage

Doppler echocardiography method provides less accurate results. It requires well trained operator.

6. *Ballistocardiographic Method*

Ballistocardiography is the technique to record the movements of the body caused by **ballistic recoil,** associated with contraction of heart and ejection of blood. It is based on **Newton's third law of motion** (for every action there is an equal and opposite reaction). When heart pumps blood into aorta and pulmonary artery, a recoiling force is exerted against heart and the body. It is similar to that of ballistic recoil when a bullet is fired from a riffle.

Pulsations due to this ballistic recoil can be recorded graphically by making the subject to lie on a suspended bed, movable in the long axis of the body. The cardiac output is determined by analyzing the graph obtained.

Advantage

The only advantage of ballistocardiography is that it is a non-invasive method.

Disadvantage

Ballistocardiography is not a commonly used technique because it involves cumbersome procedures for calibrating the equipment and analyzing the graph. It also does not provide accurate results.

CARDIAC CATHETERIZATION

DEFINITION

Catheter is a thin radiopaque tube, made up of elastic web, rubber, plastic, glass or metal. Cardiac catheterization is an invasive procedure in which a catheter is inserted **intravascularly** into any chamber of the heart or a blood vessel.

Cardiac catheterization is helpful to study the different variables of hemodynamics, both in normal and diseased states. Cardiac catheterization was discovered by a German medical student Werner Forsmann, who practiced this technique first on himself.

CONDITIONS WHEN CARDIAC CATHETERIZATION IS PERFORMED

Cardiac catheterization is generally performed:

1. When clinical assessments indicate rapid deterioration of patient's health and immediate treatment. This is the most common condition when cardiac catheterization is needed.
2. Whenever there is a need to confirm the suspected cardiac disease of a patient
3. Whenever there is need to determine anatomical and physiological status of heart and blood vessels.

PROCEDURE

Cardiac catheterization is performed by insertion of catheter into the peripheral blood vessel through skin, by needle puncture. This procedure is called **percutaneous insertion** of catheter.

Left Heart Catheterization

Left heart catheterization is done by passing a catheter through femoral artery, brachial artery or axillary artery. Catheter is guided into left ventricle under fluoroscopic observation via aorta. From left ventricle, the catheter is advanced into left atrium.

In patients with aortic stenosis or **prosthetic** (artificial) **valve,** the direct left ventricular puncture is performed. Under local anesthesia, a needle with a catheter is inserted through the thoracic wall at the level of apex beat. When the needle enters left ventricle, the catheter is advanced through the needle into left ventricle and later the needle is removed.

Latest technology includes catheterization through radial artery, which is called **transradial catheterization.**

Right Heart Catheterization

Right heart catheterization is usually performed by venous puncture via femoral vein. Catheter can also be introduced via internal jugular vein, subclavian vein or medial vein. Under **fluoroscopic observation,** the catheter is advanced into right atrium. From right atrium, it can be guided into right ventricle and also into pulmonary artery.

USES OF CARDIAC CATHETERIZATION

Cardiac catheterization is useful for both diagnostic and therapeutic purposes. It gives crucial information about the need for cardiac surgery, coronary angioplasty and other **therapeutic procedures.** It also gives information about anticipated risks and reversibility in the patient's condition during **cardiac surgery** or other **therapeutic interventions.**

Diagnostic Uses of Cardiac Catheterization

1. Blood samples are collected during cardiac catheterization to measure oxygen saturation and the concentration of ischemic metabolites like lactate
2. Cardiac output is measured by using Fick principle, indicator dilution technique or thermodilution technique during cardiac catheterization

3. Angiography is done with the help of catheterization. Angiography or **arteriography** is the diagnostic or **therapeutic radiography (imaging technique),** in which the fluoroscopic picture is used to visualize the blood filled structures like cardiac chambers, arteries and veins of heart and other blood vessels, by using a **radiopaque contrast** medium. It is used to determine the obstruction or occlusion of coronary blood vessels or other blood vessels. It is also used to determine the anomalies of coronary blood vessels.
4. Various pressures are determined by attaching a pressure transducer to the cardiac catheter.

   Right heart catheterization is used to measure:
   i. Right atrial pressure
   ii. Right ventricular pressure
   iii. Pulmonary arterial pressure
   iv. Pulmonary capillary wedge pressure.

   Left heart catheterization is used to measure:
   i. Aortic pressure
   ii. Left ventricular pressure
   iii. Left atrial pressure.

Therapeutic Uses of Cardiac Catheterization – Interventional Cardiology

Cardiac catheterization is performed for various therapeutic procedures. Interventional cardiology is a branch of cardiology that deals with performance of traditional surgical procedures by cardiac catheterization. It helps in:
1. Thrombolysis
2. Percutaneous transluminal coronary angioplasty
3. Laser coronary angioplasty
4. Catheter ablation.

1. *Thrombolysis*

Thrombolysis **(reperfusion therapy)** is the procedure used to break up and dissolve a **thrombus** (clot) in the coronary artery of patient affected by acute myocardial infarction due to coronary thrombus. Cardiac catheterization is used for intracoronary administration of **thrombolytic agents** which cause thrombolysis.

Thrombolytic agents:
i. Tissue plasminogen activator
ii. Streptokinase
iii. Urokinase.

All these thrombolytic agents convert plaminogen into plasmin, which degrades fibrin in clot and restore normal blood flow.

2. *Percutaneous transluminal coronary angioplasty*

Coronary angioplasty means the correction of narrowed or totally obstructed lumen of blood vessels by mechanical methods. In percutaneous transluminal coronary angioplasty (PTCA), a narrowed coronary artery is dilated by inflating a balloon attached to the tip of catheter that is introduced into the blood vessel. Sometimes, a **stent** (expandable wire mesh) is introduced into the corrected blood vessel by the catheter to keep the vessel in dilated state.

3. *Laser coronary angioplasty*

Catheter is also used to emit laser (Light amplification by stimulated emission of radiation) energy. Laser energy which is emitted into the occluded coronary artery vaporizes the atherosclerotic plaque in the diseased vessel. This technique is called laser coronary angioplasty.

4. *Catheter ablation*

Catheter ablation is the procedure to destroy (ablate) an area of cardiac tissue that blocks the electrical pathway or produces abnormal electrical impulses, resulting in cardiac arrhythmia such as supraventricular tachycardia (SVT) or Wolff-Parkinson-White syndrome (Chapter 96).

It involves advancing a catheter (with electrodes attached to its tip) towards the heart via either femoral vein or subclavian vein. When the catheter enters right atrium, arrhythmia is induced. Then the electrodes at the tip of catheter record the electrical potentials. By using these recordings, the area of faulty electrical site is pinpointed. This procedure is called **electrical mapping.**

Once the damaged site is confirmed, **radiofrequency energy** is used to destroy the small amount of tissue that disturbs the electrical flow through the heart. Thus, the healthy heart rhythm is restored. Tissue is also destroyed by freezing with intense cold **(cryoablation).**