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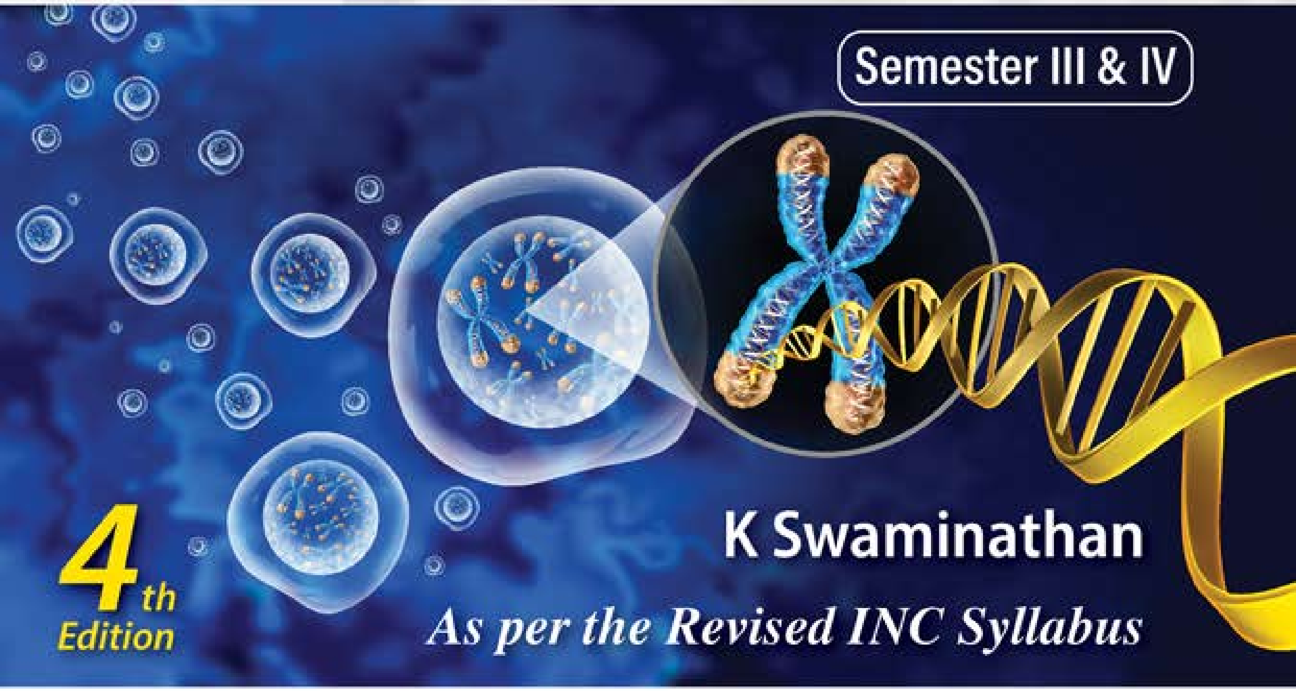
Pathology & Genetics for NURSES

A Clinically Integrated Approach with Case Scenarios & Clinical Applications

Semester III & IV



K Swaminathan

4th Edition

As per the Revised INC Syllabus

JAYPEE

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6

CHAPTER

Cardiovascular System

Learning Objectives

At the end of reading this chapter, the student shall be able to:

- Define arteriosclerosis and atherosclerosis and differentiate both of them.
- Describe the risk factors, pathogenetic mechanisms, pathology and clinical implications of atherosclerosis.
- Define aneurysm and discuss the various causes and manifestations of aortic aneurysms.
- Describe the epidemiology, risk factors, etiology, pathogenesis, pathology, clinical features, diagnosis and complications of ischemic heart disease.
- Describe the etiology, pathogenesis, pathology, and complications of rheumatic heart disease.
- Describe the risk factors, etiology, pathogenesis, pathology, clinical features and complications of infective endocarditis.
- Define cardiomyopathy. Enlist the causes for cardiomyopathy.
- Describe the etiology and pathology of the pericardial diseases.

NORMAL STRUCTURE

The blood vessels are closed circuits for the transport of blood and other nutrients. They are composed of arteries, arterioles, capillaries, venules and large veins. The anterior view of the heart with coronary arteries is shown in **Figure 6.1**.

Based on the caliber and histological features, the arteries are grouped into large elastic arteries, medium-sized muscular arteries and smaller arterioles.

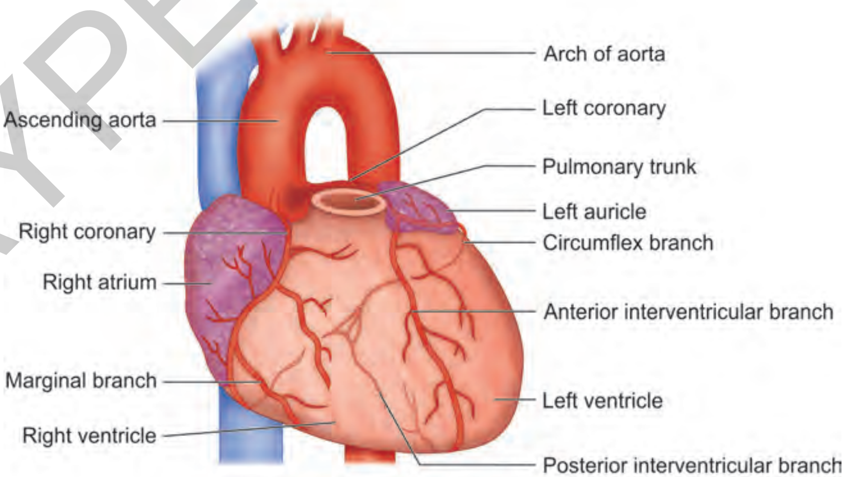


Fig. 6.1: Anterior view of coronary arteries.

Type of artery	*Examples*
Large elastic	Aorta, common carotid, common iliac
Medium muscular	Cerebral, coronary, uterine, mesenteric
Arterioles	Smaller branches of arteries

Histologically, the arteries have three layers in their wall. They are:

1. *Tunica intima:* It is the inner most layer and composed of lining endothelial cells and subendothelial collagen. It also contains the myointimal cells. It is bounded externally by the fenestrated internal elastic lamina.
2. *Tunica media:* It is the middle layer and is composed of smooth muscle cells elastic fibers and amorphous ground substance. This is the thickest of all the three layers and is limited by the external elastic lamina. This layer is responsible for vasomodulation.
3. *Tunica adventitia:* It is the outermost layer of the vessel composed of connective tissue. This layer is rich in vessels and nerves like the vasa vasorum and vasa nervosum.
   Capillaries have a similar architecture without tunica media. The veins also have a similar histomorphological pattern. The endothelium of the vein is thrown into valvular folds and the media layer is very thin and poorly developed.

PATHOLOGY OF BLOOD VESSELS

Arteriosclerosis

Definition

It is defined as a process of thickening and hardening of the vessel wall due to various conditions. The common causes are the following:

- Atherosclerosis
- Senile arteriosclerosis
- Hypertensive arteriosclerosis
- Monckeberg's arteriosclerosis.

Atherosclerosis

Definition

It is a disease of large and medium-sized muscular arteries and elastic arteries characterized by the formation of an atheromatous plaque which is a raised intimal lesion composed of lipid core and fibrous cap (**Fig. 6.2**).

It is one of the leading causes of morbidity and the major consequences of atherosclerosis are the following:

- Myocardial infarction
- Cerebrovascular accidents
- Peripheral vascular occlusive disorders—gangrene
- Abnormal dilatation and rupture of the vessel—aneurysm

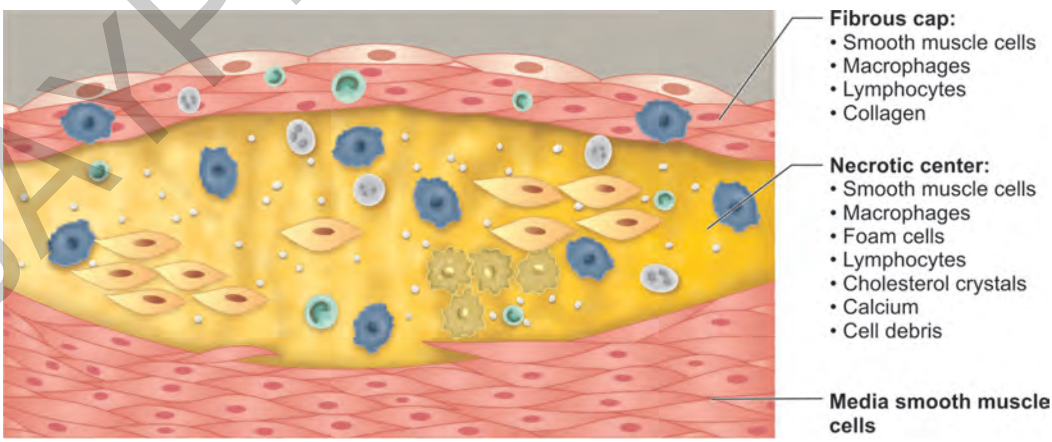


Fig. 6.2: Atheromatous plaque.

Epidemiology

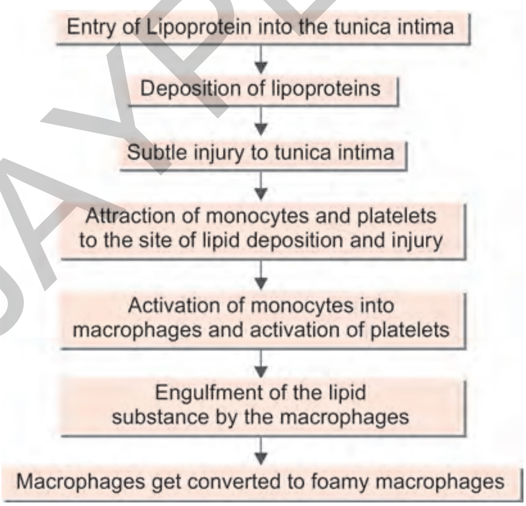
There are various risk factors which contribute to atherosclerosis and they are grouped into modifiable (soft), potentially modifiable and non-modifiable (hard) risk factors.

Non-modifiable risk factors	*Potentially modifiable risk factors*	*Modifiable factors*
Age	Diabetes mellitus	Reduced physical activity
Gender	Hypertension	Stress
Familial hyperlipidemias	Obesity	Drugs—contra-ceptive pills
Family history		Smoking
Homocystinemia		Type A personality
		Hyperuricemia

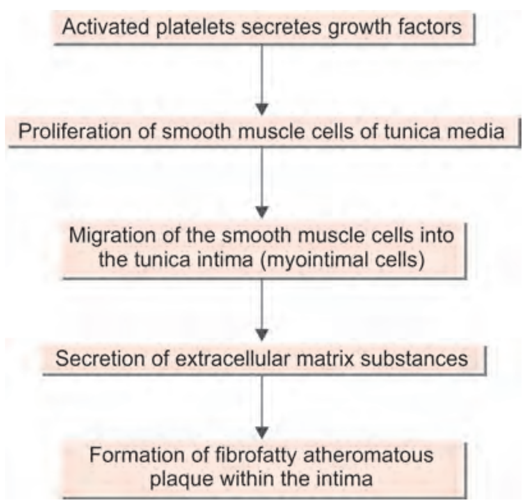
Role of the Important Risk Factors in the Evolution of Atherosclerosis

- *Age:* The incidence of atherosclerosis increases with increase in age of the individual.
- *Gender:* Up to the menopause women have a lesser chance for atherosclerosis due to the protective action of estrogen, but after menopause the incidence is same.
- *Familial hyperlipidemia and obesity:* It is one of the most important risk factors for atherogenesis. The atheromatous plaques are generally rich in lipids and a strict control of the level of the lipoproteins reduces the risk of atherosclerosis.
- *Diabetes mellitus:* It is an important predisposing factor for atherosclerosis due to following reasons. Patients with diabetes mellitus have elevated levels of triglycerides, low levels of high-density lipoproteins (HDL), reduced levels of prostacyclin and risk of endothelial cell dysfunction. All these factors play a vital role in the formation of an atheroma.
- *Hypertension*: It produces significant damage to the endothelium which is the initiating event in many forms of atherogenesis.
- *Smoking:* It increases the risk by lowering the levels of high-density lipoproteins and increasing the levels of fibrinogen.
- *Physical inactivity:* Lack of physical activity reduces the level of high-density lipoproteins which in turn contributes to atheroma formation.
- *Type A personality:* Atherosclerosis is more common in individuals who are highly

Primary Events



Secondary Events



aggressive, ambitious, bustling, impatient and short tempered.

Pathogenesis of Atherosclerosis

There are various theories and hypothesis that contribute to the formation of atheroma. The most widely accepted theory is **modified reaction to injury hypothesis**. We shall now discuss briefly the salient features of this mechanism.

Modified reaction to injury hypothesis: The mechanism is depicted in the below flowcharts:

To conclude, the four major events in atherogenesis are:

1. Endothelial cell injury
2. Hyperlipidemic state
3. Proliferation of smooth muscle cells
4. Formation of foamy macrophages

Morphology

There are various morphological forms of atherosclerosis (**Fig. 6.3**). The lesions are:

- *Fatty streak:* It is the earliest lesion characterized by the presence of multiple thin yellowish spots within the intima **(Fig. 6.3)**.
- *Gelatinous elevation:* It is the next transient lesion characterized by soft raised gelatinous lesions within the intima and is composed mostly of macrophages filled with lipid.
- *Fibrofatty plaque* (**Fig. 6.4**)*:* It is the fundamental lesion of atherosclerosis. This is a raised intimal whitish yellow lesion 3–15 mm in size which protrudes into the lumina. Each plaque has a fibrous cap and fatty core. Histologically, the fibrous cap is composed of proliferating fibroblastic cells, smooth muscle cells and extracellular matrix proteins. The inner lipid core consists of cholesterol debri, foamy macrophages, and extracellular lipid.

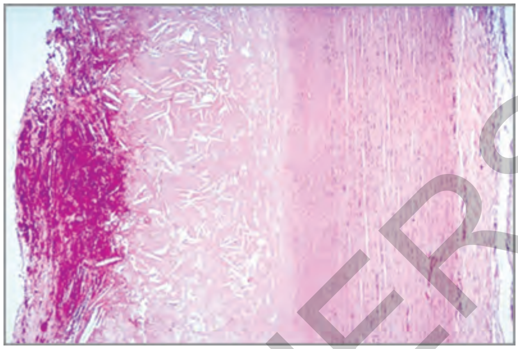


Fig. 6.4: Histomicrograph of fibrofatty atherosclerotic plaque.

Common sites for the location of atheromatous plaque:

- Abdominal aorta
- Thoracic aorta
- Ostia of the coronaries
- Popliteal
- Internal carotid
- Circle of Willis

- *Complicated plaque* (**Fig. 6.5**): This indicates advanced lesion of atherosclerosis.

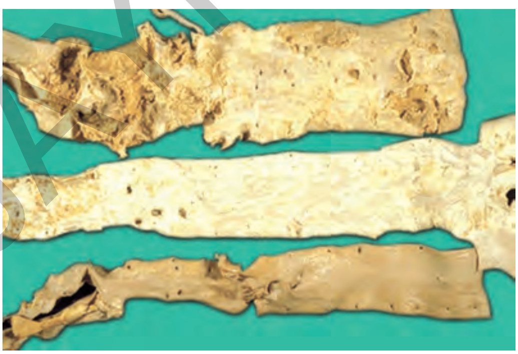


Fig. 6.3: Gross photographs of aorta showing various grades of atherosclerotic lesions.

Fig. 6.5: Ulcerated atheromatous plaque.

The changes that occur includes:
- Fibrosis of the plaque
- Ulceration of the plaque
- Formation of thrombosis
- Hemorrhage within the plaque
- Calcification of the plaque
- Thinning of the underlying vessel wall leading to formation of aneurysm.

Clinical Implications of Atherosclerosis

The various clinical implications of Atherosclerosis are summarized below:

Site of atherosclerosis	*Clinical implications*
Coronaries	♦ Myocardial Infarction, angina pectoris ♦ Cardiac arrhythmias, sudden death
Cerebral vessels	♦ Transient ischemic attack, hemiplegia ♦ Neurological dysfunction
Peripheral vessels	Intermittent claudication, gangrene
Mesenteric vessels	Bowel infarction, malabsorption
Renal vessels	Renal ischemia
Abdominal aorta	Aneurysmal dilatation

ANEURYSMS

Definition

Aneurysms are defined as localized abnormal permanent dilatation of blood vessels due to weakness of the tunica media. **Figure 6.6** depicted the types of aneurysm.

Classification criteria	*Examples*
Nature of the wall	♦ True (lined by vessel wall) ♦ False (lined by fibrous tissue)
Morphology	♦ Berry (small 1–10 mm) ♦ Saccular (sac like) ♦ Fusiform (spindle shaped) ♦ Cylindrical ♦ Cirsoid (irregular)
Etiology	♦ Atherosclerosis ♦ Syphilis ♦ Aortic dissection ♦ Traumatic ♦ Inflammatory (vasculitis) ♦ Congenital ♦ Infective (mycotic)

Classification

The aneurysms are classified based on the composition of the lining, morphology and etiology.

We shall now discuss the salient features of the most common forms of aneurysms.

❖ *Atherosclerotic aneurysms:* These are the most common forms of aneurysms. Usually seen in men above the age of 50 years.
Site: Abdominal aorta (below the origin of renal arteries and above the bifurcation of aorta) is the most common site (**Fig. 6.7**). Other vessels include superior and inferior mesenteric vessels.
The shape may be fusiform or cylindrical. The basic underlying mechanism for these

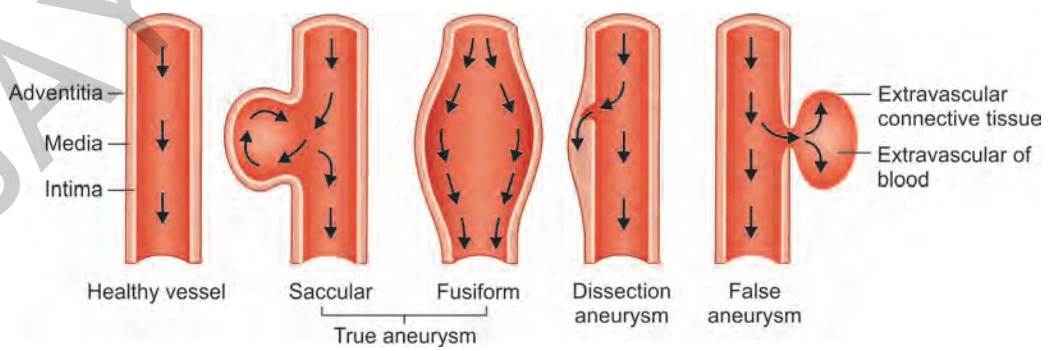


Fig. 6.6: Types of aneurysm.

Fig. 6.7: Gross photograph of atherosclerotic aneurysm of abdominal aorta.

Fig. 6.8: Cross-section of aorta showing dissection.

aneurysms is the thinning and weakening of the tunica media by long standing atheromatous lesions.

Complications: Most common complication is rupture of the aneurysm leading to massive hemorrhage, pressure effect on adjacent vital organs, thrombosis and embolization.

- *Syphilitic aneurysm:* These aneurysms are seen in the tertiary stage of syphilis and are confined to thoracic aorta. The aneurysmal sac is usually saccular or fusiform in shape. The most common underlying cause for the aneurysmal dilatation is inflammation mediated thinning of the tunica media. The basic inflammatory reaction in syphilis is obliterative endarteritis and when this involves the vasa vasorum of the vessel it leads to ischemia of the tunica media and thereby thinning. These aneurysms are often accompanied by other cardiovascular lesions of syphilis like incompetence of the aortic valve and massive left ventricular hypertrophy.

  Complications: It usually produces compressive symptoms of mediastinum, adjacent lung, esophagus and recurrent laryngeal nerve. It may also lead to erosion of the underlying bone.
- *Dissecting aneurysm:* This is a special type of aneurysm affecting the ascending and descending aorta, in which a column of blood enters into the tunica media and dissects the media, which leads to dilatation of the vessel wall **(Fig. 6.8)**.

The initial event is a tear in the tunica intima (**Fig. 6.9**). This is mostly due to a hemodynamic stress induced by hypertension. The smooth muscle cells of tunica media of the affected vessels are replaced by an amorphous basophilic material with focal cystic dilatation. This change in referred to as cystic medial necrosis. This change is due to an underlying biochemical defect in the cross-linking of collagen molecule which occurs in Marfan's syndrome. There is a mutation of a gene (fibrillin gene) in the long arm chromosome 15 (15q21) which leads to aberrant collagen cross linking.

Fig. 6.9: Gross photomicrograph of aortic dissection with an intimal tear (arrow).

In few of the cases, the blood that enters into the media reenters into the lumina due to a second tear in the intima which leads to a change called "Double barrel aorta".

Clinical profile: This condition presents with sudden onset of excruciating chest pain with increase blood pressure.

INTRODUCTION

The heart is a special type of muscular pump which ejects blood into the arterial tree to maintain optimum circulation. It is divided into four chambers—the right and left atrium and ventricles. These chambers are separate by muscular partition called interatrial septa and interventricular septa **(Fig. 6.10)**.

The flow of blood occurs in the following manner within the heart:

- Venous blood from circulation
- Right atrium
- Right ventricle
- Pulmonary artery
- Lungs—alveoli
- Pulmonary veins
- Left atrium
- Left ventricle
- Aorta
- Systemic arterial circulation

The transport of blood is regulated by a set of four cardiac valves. The atrioventricular valves are the tricuspid (right) and mitral (left). The semilunar valves are the pulmonary (right) and aortic (left).

Histologically, the heart consists of an external thin layer—pericardium, a muscular myocardium (**Fig. 6.11**) composed of the specialized cardiac muscle which has the property of conduction and inner thin endocardium, which is a specialized endothelial tissue. The endocardium that lines the valve is referred to valvular endocardium and that of the chambers, mural endocardium.

BLOOD SUPPLY

The heart is a richly vascular organ supplied by right and left coronary artery which are direct branches of aorta. The left coronary artery further divides into left anterior descending and left circumflex which supplies a major portion of heart. The right coronary artery supplies right atrium and posterior third of interventricular septum (**Fig. 6.12**). Coronary veins run parallel to the arteries and drain into coronary sinus.

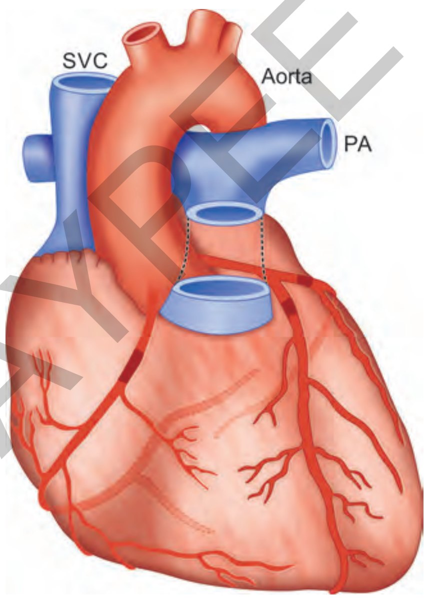


Fig. 6.10: Heart.
(SVC: superior vena cava; PA: pulmonary artery)

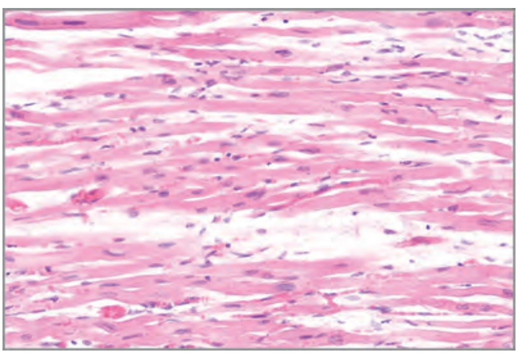


Fig. 6.11: Photomicrograph of normal myocardium.

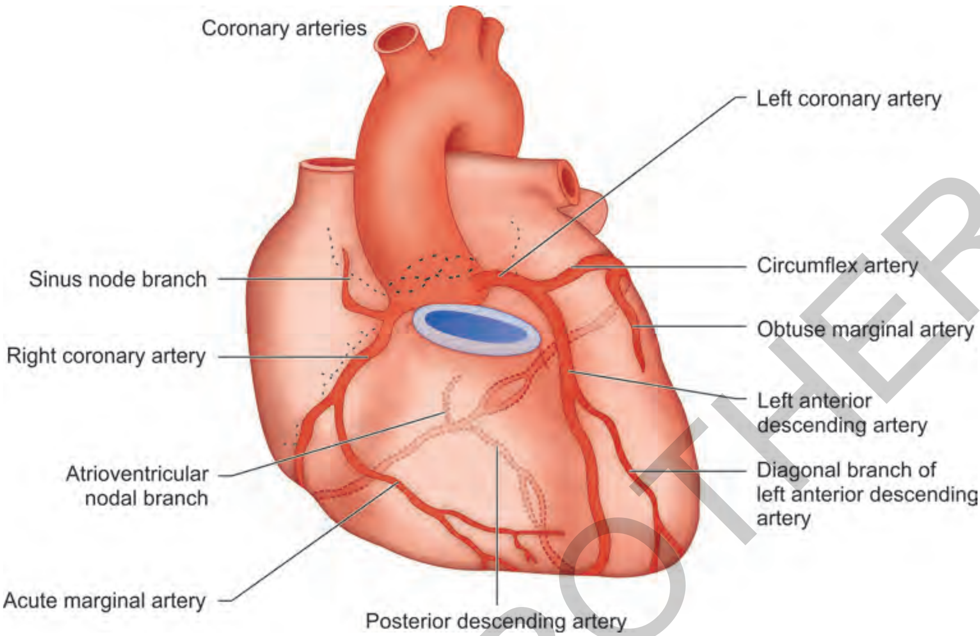


Fig. 6.12: Pattern of distribution of the coronary arteries.

DISEASES OF HEART

The diseases of the heart are categorized on the basis of the anatomic region involved and the nature of functional impairment. They are:

- *Congenital heart disease*: Due to congenital anomalies in the structure of the heart, e.g., atrial septal defect, ventricular septal defect, tetralogy of Fallot, patent ductus arteriosus, transposition of great vessels and others.
- *Ischemic heart disease*: Due to impaired blood supply to the myocardium, e.g., myocardial infarction, angina pectoris, etc.
- *Heart failure*: Due to impairment of the pumping function of the heart, e.g., left-sided and right-sided congestive cardiac failure.
- *Rheumatic heart disease*: Most common acquired immune mediated disorder of the cardiac valves, e.g., rheumatic mitral stenosis.
- *Infective endocarditis*: Valvular diseases of infective origin.
- *Cardiomyopathy*: Disorder of the cardiac musculature of unknown etiology leading to functional impairment, e.g., hypertrophic CMP, dilated CMP and restrictive CMP.
- *Hypertensive heart disease*: The changes in the heart due to hypertension.
- *Disease of pericardium*: Pericarditis, pericardial effusion.
- *Cor Pulmonale*: Disease state of the heart secondary to a chronic lung disease.
- Tumors of the heart.

Ischemic Heart Disease

It is one of the leading causes of death in both sexes in developed and developing countries.

Definition

These are group of closely related conditions resulting from myocardial ischemia. There is an imbalance between the supply and demand of oxygenated blood to the heart.

Most common causes include:

- Coronary atherosclerosis (> 90%)
- *Others*: Coronary vasospasm, coronary thromboembolism, arteritis, severe anemia, cyanotic heart diseases, advanced lung diseases.

The most common conditions included in this category of heart disease include:

1. Myocardial infarction
2. Angina pectoris
3. Chronic ischemic heart disease
4. Sudden cardiac death

Pathogenesis of Ischemic Heart Disease

The major underlying pathogenetic mechanisms that lead to ischemic heart disease are:

- Fixed coronary obstruction
- Acute changes in plaque morphology and superadded thrombi formation
- Platelet aggregation and vasospasm

Fixed Coronary Obstruction

When > 75% of the cross-sectional area of the vessel is involved by the atherosclerosis, it is called as fixed obstruction. It is mostly seen in left anterior descending, left circumflex and right coronary artery. This mostly leads to subendocardial ischemia.

Acute Changes in Plaque Morphology and Superadded Thrombi Formation

In this, a change occurs in the morphology of the plaque, such as fissuring, erosion or ulceration. This triggers thrombogenesis and a coronary thrombus is formed over the preexisting atheromatous plaque. It converts a partial obstruction into a complete one and causes transmural ischemia.

Platelet Aggregation and Vasospasm

These play a minor role in causing obstruction to the coronary circulation in association with a preexisting coronary atherosclerosis.

We shall now discuss the salient features of the various clinical entities included as ischemic heart diseases.

Angina Pectoris

Definition

It is defined as paroxysmal and recurrent attacks of substernal or precordial chest pain/discomfort due to transient myocardial ischemia that falls short of inducing an infarction and is usually relieved by rest.

The pain is usually described as constrictive, squeezing or chocking pain.

Types of Angina

There are three different types of angina—stable, variant and unstable.

1. *Stable angina*: It is the most common form of angina. Patient experiences the pain due to exertion, such as physical exercise and emotional excitement. There is an underlying chronic stenosing coronary atherosclerosis which produces subendocardial type of myocardial ischemia due to increased demand. The pain is relieved by rest or medication. Electrocardiogram shows depression of the ST segment.
2. *Variant angina* (Syn: Prinzmetal's angina): In this type of angina, the pain occurs even at rest and is not related to physical exertion. This is due to vasospasm of the coronary vessels. Electrocardiogram shows elevation of the ST segment, which indicates a transmural ischemia.
3. *Unstable angina*: This pattern is characterized by progressive increase in the pain even at rest. The duration of pain is also prolonged. It is due to acute changes in the morphology of the plaque and is a harbinger of subsequent myocardial infarction and so it is referred to as "preinfarction angina".

Case Scenario

A 48-year-old male working as a marketing executive complaints of chest pain on and off. The pain is squeezing and choking in nature and gets relieved by rest. Today he is seen in the cardiology casualty with severe chest pain of similar kind.

What is your provisional diagnosis?

Answers:
Stable angina pecrotis

There are numerous secondary factors associated with cardiomyopathy which include causes for secondary cardiomyopathy.

Causes	*Examples*
Nutritional	Beriberi, alcoholism, vitamin E deficiency
Toxins	Cobalt, arsenic, lithium, serotonin
Drugs	Adriamycin, cyclophosphamide
Metabolic	Amyloidosis, hemochromatosis, storage disorders
Neuromuscular	Friedreich's ataxia, muscular dystrophy
Connective tissue disorders	Systemic lupus erythematosus, rheumatoid arthritis, dermatomyositis
Malignancy	Leukemia
Geochemical	Deficiency of magnesium and increased levels of cerium in soil

The diagnosis of cardiomyopathy is made based on the clinical examination and echocardiographic findings. Endomyocardial biopsy is very useful in rendering a tissue diagnosis in case of cardiomyopathy.

Point to Ponder

- Arteriosclerosis is defined as a process of thickening and hardening of the vessel wall due to various conditions.
- Atherosclerosis is a disease of large and medium-sized muscular arteries and elastic arteries characterized by the formation of an atheromatous plaque which is a raised intimal lesion composed of lipid core and fibrous cap.
- Aneurysms are defined as localized abnormal permanent dilatation of blood vessels due to weakness of the tunica media.
- The diseases of the heart are categorized on the basis of the anatomic region involved and the nature of functional impairment. They are:
  - Congenital heart disease—due to congenital anomalies in the structure of the heart, e.g., atrial septal defect, ventricular septal defect, tetralogy of Fallot, patent ductus arteriosus, transposition of great vessels and others.
  - Ischemic Heart disease—due to impaired blood supply to the myocardium, e.g., myocardial infarction, angina pectoris, sudden cardiac death and chronic ischemic heart disease.
  - Heart failure—due to impairment of the pumping function of the heart, e.g., left-sided and right-sided congestive cardiac failure.
  - Rheumatic heart disease—most common acquired immune mediated disorder of the cardiac valves, e.g., rheumatic mitral stenosis
  - Infective endocarditis—valvular diseases of infective origin.
  - Cardiomyopathy—disorder of the cardiac musculature of unknown etiology leading to functional impairment, e.g., hypertrophic, dilated and restrictive.
  - Hypertensive heart disease—the changes in the heart due to hypertension.
  - Disease of pericardium—pericarditis, pericardial effusion.

ASSESSMENT QUESTIONS

Essay Type Questions

1. **Define atherosclerosis. Enlist the common risk factors for atherosclerosis. Describe in detail the pathogenesis and pathology of atherosclerosis. Add a note on the clinical implications.**
2. **A 22-year-old person was rushed to the casualty with excruciating chest pain radiating to the back with excessive sweating and palpitation. His pulse rate was 102/mt. His blood pressure was 180/100 mm Hg. He was tall for his age with tall and lax fingers. He also had ophthalmic problems. One of his uncle also had a similar problem.**
   a. What is your provisional diagnosis?
   b. Substantiate your answer.
   c. Enlist the differential diagnosis in this case.
   d. Mention the brief pathogenesis of this condition.
   e. What are the common predisposing factors of this condition?
3. **A 59-year-old CEO of a multinational company was rushed to the medical emergency room with severe chest pain. The pain was acute and radiating to the left shoulder. He had a bout of vomiting and has nausea now.**

   Past history: The patient had similar episodes before and was on medications.

   On examination the patient is in shock with weak thready pulse, blood pressure is 90/60 mm Hg.
   a. What is your provisional diagnosis?
   b. Substantiate your answer.
   c. Enlist the differential diagnosis in this case.
   d. List the investigations that will help you to arrive at the correct diagnosis.
   e. Mention in brief the pathogenesis of this condition.
   f. Enumerate the complication of this condition ?
4. **A 10-year-old boy was seen in the department of pediatrics with difficulty in breathing, on and off chest pain, cough with expectoration. He had similar episodes before and was on medications. The person had fever with painful joints two years back and was treated in the same hospital.**

   On examination thin built boy, mild anemia, not jaundiced. Pulse and BP within normal limits.
   a. What is your provisional diagnosis?
   b. Substantiate your answer.
   c. Enlist the differential diagnosis in this case.
   d. Mention in brief the pathogenesis of this condition.
   e. What are lesions you will see in the heart of this person?
   f. List the common investigations you do in this case.
   g. Enumerate the complication of this condition?

5. **A 22-year-old person was seen in the medical OPD with high fever for the past one week. The fever was irregular with spikes and he had local medication.**
   On examination, the patient is febrile, anemic, spleen is palpable. No hepatomegaly.
   He was diagnosed to have a cardiac valvular disease and was on irregular follow up with the cardiology department.
   a. What is your provisional diagnosis?
   b. Substantiate your answer.
   c. Enlist the differential diagnosis in this case.
   d. Mention the common predisposing factors for this pathology.
   e. What are lesions you will see in the heart of this person?
   f. What is the diagnostic criteria for this condition?
   g. Enumerate the complication of this condition.

Short Answer Questions

1. **Name the nonmodifiable risk factors for atherosclerosis.**
2. **Enumerate the functions of oxidized low density lipoproteins.**
3. **What are the common sites of occurrence of atheromatous plaque?**
4. **Enumerate the common etiological factors for aneurysm.**
5. **Enumerate the four anatomical changes that define tetralogy of Fallot.**
6. **Enlist the various disease entities included in IHD.**
7. **Enumerate the differences between subendocardial and transmural infarct.**
8. **Enlist the common complications of acute myocardial infarction.**
9. **What is acute rheumatic fever?**
10. **What is an Aschoff body?**
11. **Enumerate the differences between acute and subacute infective endocarditis.**
12. **Enumerate the common causes for serofibrinous pericarditis.**
13. **Define cardiomyopathy.**
14. **Name the diagnostic modalities available for the diagnosis of cardiomyopathy.**
15. **Enlist the causes for hemorrhagic pericarditis.**

MULTIPLE CHOICE QUESTIONS

1. **Fixed stenosis of a coronary refers to occlusion of __________ in its cross-section.**
   A. 25%
   B. 35%
   C. 60%
   D. 75%
2. **Sudden death in acute myocardial infarction is mostly due to:**
   A. Pulmonary edema
   B. Ventricular fibrillation
   C. Cardiogenic shock
   D. Ventricular rupture
3. **The most common type of pericarditis in acute rheumatic fever is:**
   A. Serous
   B. Fibrinous
   C. Serofibrinous
   D. Purulent
4. **McCallum's patch is seen in:**
   A. Rheumatoid arthritis
   B. SLE
   C. Rheumatic fever
   D. Polyarteritis nodosa

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- All topics are discussed in alignment with the syllabus prescribed by the Indian Nursing Council (INC).
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Medical Publishers (P) Ltd.
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Daryaganj, New Delhi - 110 002, INDIA
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ISBN 978-93-5696-856-1

9 789356 968561