27th Edition

GOLWALLA'S MEDICINE FOR STUDENTS

A Reference Book for The Family Physician

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CHAPTER

4

The Cardiovascular System

Case Vignette

Clinical summary: A 55-year-old male presented with exertional chest pain of 3 months duration. He was chronic cigarette smoker (01 packet per day) for last 15 years. Clinically he had hypertension (Blood Pressure-156/96 mm Hg) and rest of systemic examination was normal.

Relevant investigations: His ECG showed left ventricular hypertrophy. His echocardiogram showed mild concentric LVH with normal LV function and no regional wall motion abnormality. He had raised LDL cholesterol levels (LDL-194 mg/dL) and rest of basic investigations were normal. His coronary angiography showed coronary artery disease-single vessel disease (Mid Left anterior descending artery 90% lesion).

Management: He was started on dual antiplatelet (Ecosprin and Clopidogrel) and statins (Atorvastatin) along with single antihypertensive (Telmisartan). He was advised life style and dietary modification. He underwent per cutaneous coronary intervention (PCI) to mid LAD using a drug eluting stent. He became asymptomatic and normotensive. He needs regular follow-up to monitor his blood pressure and lipid control.

INVESTIGATIONS IN CARDIOVASCULAR DISEASES

BLOOD

Full blood count, measurement of serum electrolytes and urea, uric acid, serum lipids, homocysteine. Thyroid function tests. Troponin and brain natriuretic peptide (BNP) levels

CHEST RADIOGRAPH

The structures to be observed are:

- The heart for size, chamber enlargement, valvular and other calcification.
- Lungs for pulmonary venous hypertension, pulmonary edema and pulmonary ossification.
- Mediastinum for aorta, superior vena cava, pulmonary arteries and veins.
- Thorax for depressed sternum and rib notching.

ELECTROCARDIOGRAM

The ECG is the first line investigation for patient presenting with cardiac symptoms and it is especially useful when:

- Patient has chest pain, breathlessness, presyncope, palpitations or syncope
- Cardiac rhythm is irregular.
- In presence of cardiac enlargement.
- Heart murmurs are heard or heart failure is present.
- Exercise testing is useful in diagnosis of ischemic heart disease.

HOLTER MONITORING

The equipment is a battery-powered recorder which samples ECG data. These recorders allow up to 72 hours of continuous monitoring. Extendable loop recorder (ELR) can record data up to 7–15 days and implantable loop recorder (ILR) can monitor data up to 01-year data.

Clinical Uses

- To diagnose arrhythmias
- Assess antiarrhythmic therapy
- Assess pacemaker or implanted cardioverter defibrillator (ICD) function
- Determine prognosis

TREAD MILL TEST (TMT) ECG

Indications

- **Ischemic heart disease:** (a) Diagnosis. (b) Risk stratification. (c) Assessment of suitability for and assessment of exercise training and rehabilitation. (d) Follow-up of patients with known CAD. (e) Screening asymptomatic men >40 years of age who are in specific professions (pilots, firemen, vocational drivers).
- **Bradycardia and arrhythmias:** (a) Diagnosis in patients with exercise-related palpitations, dizziness or syncope. (b) Assess chronotropic competence

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Criteria for High-risk TMT

- **ST segment changes:**
  - ST segment depression ≥2 mm
  - ST segment depression ≥1 mm at <5 metabolic equivalents (METs)
  - ST segment elevation ≥2 mm (not in q wave lead or aVR)
- **Low exercise capacity:**
  - <5 METs
  - <100% age predicted METs = 14.7-(0.13X age)
- High risk Duke Treadmill score (DTS) = Exercise time –(5X ST change) –(4X Angina Index)
- Decrease in systolic blood pressure >10 mm Hg from rest
- Poor heart rate recovery
- Ventricular rrhythmia.

ECHOCARDIOGRAPHY AND DOPPLER ULTRASOUND

The heart can be imaged with echocardiography which provides detailed data on cardiac structure as well as morphology and function of heart valves. It is based on ultrasound imaging in which high frequency sounds in the 1-10 MHz range are emitted from piezoelectric crystals which traverse through body tissues, reflected to transducer and then processed by microcomputers to generate an image.

Cross-sectional Echocardiography (CSE or 2D ECHO)

Here multiple ultrasound beams, each produced by a single ultrasound crystal or by mechanically scanning the heart with a single crystal create a sector-shaped cross-section of the heart. Between 30 and 50 such cross-sections are built-up per minute and presented as a moving picture. Imaging planes such as parasternal, apical or subxiphoid are used to produce a complete picture of the heart. While 2D echocardiography does provide an accurate method for assessment of LV function, systolic 3D provides an accuracy in the assessment of LV volumes and can be compared with gold standards such as cardiac MRI or radionuclide volumes **(Figs. 4.1 to 4.3)**.

Advances in Echocardiography

There have been significant technical developments in echocardiography technology which has led to improved imaging capabilities; which include three-dimensional echo (3D echo), tissue strain imaging, contrast echocardiography and handheld echo probes.

Table 4.1 gives various modalities of echocardiography and their uses.

Transthoracic Echocardiography

Indications: See **Table 4.2**.

Transesophageal Echocardiography (TOE)

By mounting both imaging and Doppler transducers on a gastroscope, the heart can be interrogated from the esophagus. Since there is little tissue between the heart and the transducer, high quality pictures can be obtained. *Advantages*—(a) Excellent access and superior imaging.

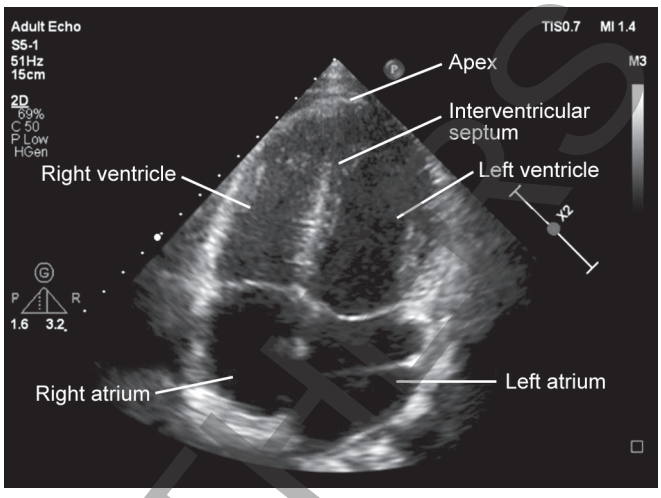

Fig. 4.1: 2D echo apical 4 chamber view showing normal heart.

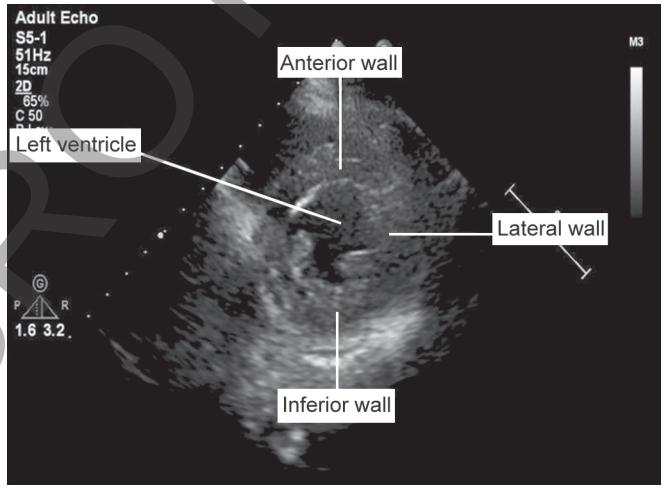

Fig. 4.2: 2D echo parasternal short axis view showing normal heart.

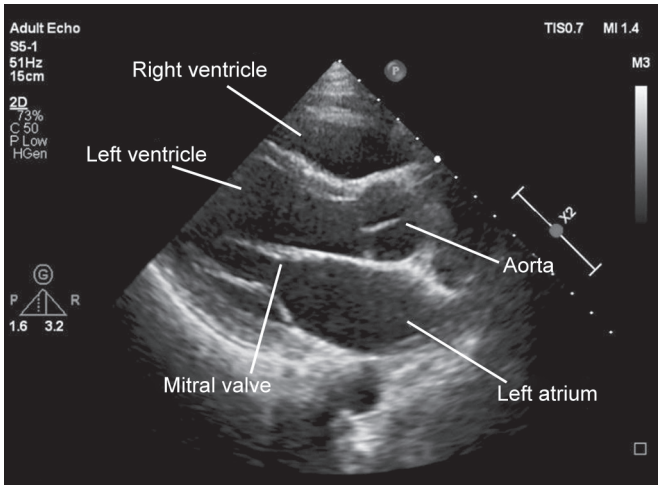

Fig. 4.3: 2D echo parasternal long axis view, normal heart.

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TABLE 4.1: Modalities of echocardiography and their uses.

Two-dimensional imaging	• To describe anatomy and motion • To measure cavity size and wall thickness • To measure LV outflow tract diameter for calculation of stroke volume • To estimate LV volumes and ejection fraction • Planimetry of the orifice of mitral valve in mitral stenosis
M-mode	• Measurement of cavity size and wall thickness • Estimation of LV mass • Timing of events within the heart • In combination with color flow mapping aids timing of a flow pattern
Continuous wave Doppler	• Calculates the grade of stenotic valve lesions • Estimates pulmonary artery pressure • Semiquantitative assessment of the grade of valve regurgitation
Pulsed Doppler	• Assesses diastolic LV function from recording at the mitral valve and in a pulmonary vein • Estimates orifice area of aortic valve (in combination with 2D imaging and continuous wave Doppler) • Calculates stroke volume and cardiac output Estimates shunt size
Color flow mapping	• Screens for abnormal flow, e.g., valve regurgitation or a shunt • Semiquantitative estimate of grade of valve regurgitation
Doppler tissue	• Detecting asynchrony of imaging contraction, e.g., early depolarization in Wolff-Parkinson-White syndrome or the origin of ventricular tachycardia • Describing diastolic and systolic function including time intervals, regional function, long axis function and differences between endocardial and epicardial function

TABLE 4.2: Indications for echocardiography.

• *Congenital heart disease*
• *Ischemic heart disease*
– Diagnosis of acute chest pain
– Stress echocardiography
– Complications of MI
– Detection of viable myocardium
• *Heart failure*
– Diagnosis of mechanism, e.g., predominant systolic or diastolic dysfunction, dilated cardiomyopathy vs restrictive heart muscle disease
– Diagnosis of cause, e.g., IHD, unsuspected AS
– Estimation of ventricular filling pressures
– Assessment of global LV function and prognosis
• *LV hypertrophy*
• *Hypertrophic cardiomyopathy*
• *Pericardial effusion and constriction*
• *Valvular heart disease*
– Diagnosis and quantitation of valve stenosis or regurgitation
– Mitral valve prolapse
– Infective endocarditis
– Monitoring function of prosthetic heart valves
• *Suspected cardiogenic embolism or intracardiac thrombus* (in conjunction with TOE)
• *Suspected cardiac tumor*, e.g., myxoma
• *Miscellaneous*
– Fetal echo when obstetric surveillance suggests a possible cardiac problem
– Neonatal with cyanotic CHD
– Older children: To exclude significant disease in patients with innocent systolic murmurs
– Adult survivors of surgery for complex CHD developing problems

(b) Valves closer to transducer, hence vegetations, and prosthetic valve function more easily seen. (c) Clear vision of ascending and descending aorta.

Indications for Transesophageal echocardiography (with preparatory transthoracic study) are given in **Table 4.3**.

Stress Echocardiography

Stress echocardiography is used to predict the presence of coronary disease, to stratify the risk of a coronary event, and to detect hibernation. It is also used for assessment of functional reserve in patients with end-stage valve disease **(Table 4.4)**.

Echocardiography in Suspected Heart Failure

Indications

- Breathlessness or dependent edema and clinical findings that suggest or cannot exclude heart disease
- Unexplained hypotension
- Exposure to cardiotoxic agents
- Known cardiomyopathy where there is a change in cardiac status

Echocardiography in Valve Disease

Indications for echocardiography in valvular heart disease are listed in **Table 4.5**.

Echocardiography for Screening

- Family history of genetically transmitted cardiovascular disease, e.g., Marfan syndrome, hypertrophic cardiomyopathy, dilated cardiomyopathy

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TABLE 4.3: Indications for transesophageal echocardiography.
Suspected endocarditis
• In all cases of prosthetic valve endocarditis
• If transthoracic study is nondiagnostic
• Consider in all cases of native endocarditis
Cerebral infarction, TIA, peripheral embolism
• Patients without evidence of cerebrovascular disease or other obvious cause
Prosthetic valve
• To improve quantification of MR
• Suspected endocarditis
Native valve disease
• To determine feasibility and safety of balloon mitral valvotomy and to look for left atrial appendage clot
• To determine whether some cases of MR are repairable
Atrial septal defect
• To determine whether percutaneous closure is possible
Aorta
• To diagnose dissection, intramural hematoma
• To determine the size of the aorta if not clear transthoracically
Intraoperative
• To monitor left ventricular function
• To assess de-airing of the heart after cardiac surgery
• To assess the result of valve repair
Intensive care unit
• To assess loading, LV and RV function and valve function

TABLE 4.4: Indications of stress echocardiography.
• Clinical uncertainty and normal or equivocal conventional exercise test
• Patient unable to exercise
• Resting ECG precluding electrical analysis (e.g., LBBB, LV hypertrophy with strain, digoxin)
• Risk stratification after acute MI
• Need to localize site of ischemia
• To assess functional significance of a coronary stenosis in planning angioplasty or surgery
• To detect hibernating myocardium
• To grade aortic stenosis in presence of a low LV ejection fraction
• To determine if MR develops or worsens during strain

- Potential donors for cardiac transplantation
- Baseline and re-evaluation of patients undergoing chemotherapy with cardiotoxic agents

TABLE 4.5: Indications of echocardiography in valve disease.
• If patient is previously uninvestigated and symptomatic disease
• Murmur suggesting a moderate probability of organic disease
• Ejection systolic murmur filling most of systole or any pansystolic murmur
• Any diastolic murmur
• Abnormal second heart sound
• Wide pulse pressure and displaced apex beat or enlarged cardiac shadow
• Re-evaluation if there is LV dilation even if valve disease is mild or moderate
• Re-evaluation if symptoms change or with severe valve disease even with no symptoms
• Evidence of endocarditis
• Known significant valve disease and pregnancy
• For planning valve replacement, repair or valvotomy
• Routinely soon after valve surgery or if symptoms or signs suggest dysfunction

CARDIAC CT

It demonstrates whether the coronary tree is normal or abnormal. Also, if the test is abnormal, it can tell the extent of abnormality which can range from minor disease (calcified, noncalcified plaques) to severe stenosis and occlusions. Coronary artery calcium (CAC) can be evaluated based on Agatston score. CAC score of 0 has been associated with very low adverse cardiovascular outcomes (less than 1% mortality per year).

Indications for Cardiac CT to rule out CAD (a) Family H/o CAD (b) Atypical chest pain. (c) Pre-adult congenital heart disease or cardiac tumor surgery. (d) Premajor surgery in adults over age of 50. (e) Smoking. (f) Equivocal ECGs, echocardiograms or after stress studies as routine check-up.

MAGNETIC RESONANCE IMAGING (MRI)

It is a powerful tool providing high-resolution images of the heart and great vessels without the use of ionizing radiation or contrast agents. It can provide details about LV function, viability, inflammation, cardiomyopathy, valvular diseases, pericardial diseases, congenital heart diseases, cardiac tumors etc. **(Figs. 4.5 and 4.6)**.

NUCLEAR CARDIOLOGY

It is the study of cardiac function, myocardial perfusion and blood flow, myocardial metabolism and myocardial damage with radio-active molecules and gamma camera.

- The most common imaging procedure in nuclear cardiology is single photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI).

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Fig. 4.4: A 3D Gd-DTPA-enhanced MR angiogram of a 3-year-old patient with a significant coarctation of the descending aorta just distal to the subclavian artery.



Fig. 4.5: Parasagittal 2-chamber long axis T1-weighted gradient echo cine image of a large left atrial myxoma (large round mass with low signal intensity) attached to the superior pole of the left atrium and prolapsing across the mitral valve.

The common indications of perfusion scan are discussed in **Table 4.6**. It can detect the viability of myocardium as well as reversible perfusion defects which can decide the revascularization strategies. One important and frequent indication is patient at low to intermediate probability of CAD who either have noninterpretable ECG (e.g., LBBB) or those who cannot exercise. Various tracers are used for various applications, e.g.,

- Thallium-201 (^{201}Tl), Technetium 99m (^{99m}Tc), etc. Patient can be subjected to either treadmill exercise, if feasible else pharmacological stress can be given using drugs, e.g., dobutamine. Presence of reversible perfusion defect and wall motion abnormalities in specific coronary territory indicates significant coronary artery disease which might benefit from revascularization. Presence of fixed perfusion defect indicate scar where benefit of revascularization is doubtful. Transient ischemic dilation of ventricle and significant lung uptake in the study provides clues towards extensive CAD.
- Another important cardiac evaluation strategy in nuclear cardiology ispositron emission tomography (PET). The measurement of myocardial perfusion and metabolism can be obtained in absolute quantitative terms. The radiotracers used in PET are labeled with positron emitting isotopes. The perfusion tracers are rubidium-82 (^{82}Rb) and ^{13}N-ammonia and the myocardial metabolic tracer is 2-^{18}F- fluoro-2-deoxygluose (FDG). PET scan gives information about myocardial blood flow, assessment of infarct size, viability of myocardium, etc.
- Radionuclide ventriculography—It is usually performed using equilibrium technique, i.e., multiple gated acquisition technique (MUGA) scanning. It is preformed when accurate estimate of ventricle function is required especially right ventricle which is usually difficult to visualize by conventional echocardiography.

TABLE 4.6: Indications of myocardial perfusion imaging.

• Risk stratification in IHD.
• Management and follow-up after therapeutic interventions, e.g., coronary angioplasty or surgery
• Prognostic assessment
• Detection of myocardial viability in ischemic LV dysfunction.

CARDIAC CATHETERIZATION

Indications

- **Intracardiac shunt and congenital heart diseases:** Help in assessment of shunt anatomy, fraction, anatomy of great vessels and potential intervention.
- **Valvular heart disease:** Preoperative assessment, hemodynamic assessment for pulmonary hypertension, determine severity of aortic stenosis, etc.
- **Pericardial disorders:** To detect and assess restrictive or constrictive pericarditis.
- **Other:** Ischemic heart disease, LV dysfunction of unknown etiology.

Procedure

It is an invasive procedure which involves artery and venous access (usually femoral), introduction of various catheters in the chambers of heart/great vessels, assessment of intracardiac pressure/oxygenation, calculation of cardiac output, etc. This diagnostic procedure can be combined with other intervention procedure such as angioplasty, valvuloplasty, device closure, etc.

The normal pressure and resistance are as follows **Table 4.7**:

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TABLE 4.7: Mean pressures across heart chambers

Sl. No.	Pressure	Mean (mm Hg)	Range (mm Hg)
1.	Right atrium		
a.	A wave	6	2–7
b.	V wave	5	2–7
c.	Mean	3	1–5
2.	Right ventricle		
a.	Peak systolic	25	15–30
b.	End diastolic	4	1–7
3.	Pulmonary artery		
a.	Peak systolic	25	15–30
b.	End diastolic	9	4–12
c.	Mean	15	9–19
4.	Pulmonary capillary wedge		
a.	Mean	9	4–12
5.	Left atrium		
a.	a wave	10	4–16
b.	V wave	12	6–21
c.	Mean	8	2–12
6.	Left ventricle		
a.	End diastolic	8	5–12
7.	Vascular resistance	Mean (Dyne-sec.cm^{-5})	Range (Dyne-sec.cm^{-5})
a.	Systemic vascular resistance	1100	700–1600
b.	Pulmonary vascular resistance	70	20–130

Complications

- Damage to arteries and veins with possible thrombo-embolism.
- Production of arrhythmia.
- Introduction of infection.

CORONARY ANGIOGRAPHY (CAG)

Coronary angiography is the most common interventional procedure performed currently. This entails visualization by X-ray of contrast material injected into arteries, veins or heart chambers to define anatomy, disease or direction of blood flow. Basically, there are 3 types of angiography currently available—(1) Conventional film-screen angiography. (2) Intravenous digital subtraction angiography. (3) Intra-arterial digital subtraction angiography.

Coronary cine-angiography: It is performed by arterial catheterization under local anesthesia, usually by percutaneous puncture of femoral or radial artery. A catheter is introduced and guided under radiological control to the left ventricle and left and right coronary arteries in turn. Contrast medium is injected while video and cine images of the recordings are made.

Intracoronary imaging: Special catheters can be passed into the coronary arteries to visualize plaque composition, calcification and to plan angioplasty. Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) are two such tools.

Coronary physiology assessment: Various advanced tools are now available which assess the ischemic potential of coronary lesion. Fractional flow reserve (FFR) and resting flow cycle ratio (RFR) are two of such widely used tools.

DIGITAL SUBTRACTION ANGIOGRAPHY

Digital subtraction angiography (DSA) is a form of angiography where with the help of a computer, a clear image of the blood vessel (without bone overlap) can be obtained.

IV DSA

Principle—The image acquisition system in DSA consists of a specially designed X-ray image intensifier and television video chain coupled to an image processor, where images are recorded, manipulated and displayed on a cathode ray tube. Images are converted into a digital format. Images obtained before the appearance of contrast material are subtracted from the images obtained after arrival of contrast material in the vessels, so that the resultant image is that of an isolated contrast contained arterial structure. The image is then electrically contrast enhanced to display the final image to its best advantage.

Technique—An antecubital vein is punctured with an 18 gauge needle. A guide wire is then threaded into SVC through the needle. The needle is withdrawn and a 5F high flow digital catheter is introduced over the guide wire and placed into the right atrium the vessel or chamber which needs to be analyzed. The transit time for the contrast material to reach the arterial vessel in question ranges from 4 to 30 seconds. Total dose of contrast material is 150–200 mL.

Indications for DSA in cardiovascular cases **(Table 4.8)**.

Advantages

- Simple and safe method and out-patient procedure.
- Avoids arterial puncture complications.

TABLE 4.8: Indications for DSA in cardiovascular cases.

- To screen young hypertensives for renovascular cause
- Occlusive disease of aorta and peripheral vessels
- Pulsatile masses to rule out aneurysm
- In the pediatric age group as safe alternative to angiography
- Postoperative evaluation, e.g., graft patency
- Follow-up after angioplasty

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BOX 4.1: Diagnosis in cardiology.

Clinical history and physical examination		
Diagnostic test for atherosclerotic coronary artery disease evaluation	***Diagnostic test for heart disease evaluation***	***Diagnostic test for arrhythmia evaluation***
Functional information providing tests • Exercise ECG • Stress echocardiography • Nuclear SPECT perfusion • Dobutamine echocardiography • Vasodilator nuclear perfusion (adenosine, dipyridamole) • Dobutamine nuclear perfusion • PET/CT • Dobutamine OR adenosine CMR	• Transthoracic echocardiography • Transesophageal echocardiography • Three-dimensional echocardiography • Radionuclide angiography • Multigated acquisition (MUGA) • Cardiac catheterization • Coronary CT angiography • CMR imaging • Chest CT with contrast	• Resting ECG • Ambulatory ECG (Holter monitors) • Exercise ECG • Long-term ECG • Patient triggered event recorder • ILR implantable loop records • Mobile cardiac outpatient telemetry • Electrophysiology study (EP study)
Anatomical information providing test • Coronary angiography • Coronary artery calcium (CAC) scoring • Coronary CT angiography		

Limitations

- Patient should be co-operative and have reasonable cardiac output.
- Less spatial resolution.
- Not suitable for patients with renal failure because of high volume of contrast.

Box 4.1 shows the summary of diagnostic testing in cardiology.

Take Home Points

- Cardiovascular investigations help detect heart and vessel abnormalities early, guiding diagnosis, risk stratification, and management strategies.
- Investigations aim to identify underlying causes like atherosclerosis, hypertension, valvular defects, or congenital anomalies.
- Symptoms like chest pain, dyspnea, palpitations, and syncope prompt the need for cardiovascular evaluation and testing.
- ECG, echocardiography, cardiac enzymes, stress testing, and angiography are essential tools in diagnosing heart diseases.
- Investigation results guide treatment decisions such as medical therapy, interventions (angioplasty), or surgical correction (bypass, valve repair).

IMPORTANCE OF CLINICAL EXAMINATION

SYSTEMIC EXAMINATION

- Central cyanosis indicate right to left shunting. Peripheral cyanosis can be seen in severe heart failure, shock or peripheral vascular diseases. Clubbing implies central shunting.
- Waist circumference, waist to hip ratio and body mass index are predictors of long term cardiovascular risk.
- Abnormal breathing pattern may represent obstructive sleep apnea, heart failure or central sleep apnea.
- Ecchymosis can be seen in patients on anticoagulants/antiplatelets. Petechiae indicate thrombocytopenia and purpura can be associated with vasculitis or infective endocarditis. Xanthoma and xanthelsma indicate underlying lipid disorders which may predispose for CAD.

PULSE

- **Rate:** No absolute normal. Varies in different individuals and in same individual under different circumstances. In the adult male at rest during waking stage, rate varies between 60 and 80 per minute and in adult female from 70 to 90 per minute. The pulse is slower during sleep. *Bradycardia* is pulse rate less than 60 per minute. *Tachycardia* is pulse rate more than 100 per minute. *Pulse apex deficit*—The pulse rate corresponds to heart rate except in the presence of premature contractions or atrial fibrillation, where some of the beats are not transmitted to the radial pulse so that the heart rate exceeds the pulse rate.
- **Rhythm:** Normal pulse is regular in rhythm. For bedside diagnosis it is important to observe whether the rhythm is regular or irregular and whether the rate is unusually rapid or slow or normal **(Table 4.9)**.
- **Volume:** Corresponds to amplitude of the movement or lift of the vessel wall during the passage of the pulse wave. The volume depends on cardiac output **(Table 4.10)**.
- **Force:** Corresponds to systolic blood pressure. Press the radial artery against the underlying bone with the more proximal of the two palpating fingers till the pulse wave is no longer felt with the distal finger. More the pressure required to obliterate the pulse higher the systolic blood pressure.

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TABLE 4.9: Abnormalities of rate and rhythm of pulse.

Causes of bradycardia
• *Regular rhythm*
– Sinus bradycardia: Physiological (Athletes) or pathological (hypothyroidism, obstructive jaundice, etc.)
– Complete heart block or AV block with regular ventricular rate
– Junctional rhythm (Nodal rhythm)
• *Irregular rhythm*
– Sinus bradycardia with sinus arrhythmia
– SA or AV block: Partial heart block with irregularly dropped beats
– Atrial fibrillation with slow ventricular rate
Causes of tachycardia
Regular rhythm
• Sinus tachycardia
• Paroxysmal tachycardia
• Atrial flutter
Irregular rhythm
• Atrial fibrillation
• Sinus tachycardia with ectopic beats
• Atrial flutter with varying block
• Paroxysmal atrial tachycardia with block
Causes of irregular rhythm with normal heart rate:
• Multiple ectopics
• Slow atrial fibrillation
• Sinus arrhythmia

- **Rate of rise or ascent of pulse:** Normal rate of rise of pulse signifies absence of significant obstruction of outflow at aortic valve. (i) *Rapidly rising pulse*–Light application of examining finger elicits a sharp tap or slap. Very rapid rate of rise with large pulse volume in aortic regurgitation, PDA, thyrotoxicosis. (ii) *Slowly rising pulse*– in aortic stenosis (Pulsus parvus et tardus).
- **Condition of arterial walls:** In arteriosclerosis, the vessel is palpable and can be rolled between the fingers. The inelasticity of a rigid artery may cause a strong pulse to appear weak.
- **Inequality of pulse:** It is essential to feel one of the larger pulses, such as the carotid or brachial, and the main peripheral pulses should also be felt for. Coarctation of aorta can give rise to discrepant pulses, and an absent or diminished left brachial pulse indicates that the obstruction is at or proximal to the left subclavian artery. Weakness of pulse at the wrist on one or other side may be due to various causes listed in **Table 4.11**.
- **Radio-femoral lag:** In coarctation of aorta, the femoral pulse is delayed when compared to the radial and not synchronous as in normal subjects.

TABLE 4.10: Causes of abnormal pulse volume.

Pulse of large volume: In *high cardiac output states*—
Physiological:
• After exercise
• Pregnancy
• Warm humid environment.
Pathological:
• Anemia
• Fever
• Thyrotoxicosis
• Cor pulmonale
• Cirrhosis of liver
• Systemic A-V fistula
• Systemic hypertension
• Beriberi heart disease
• Paget's disease
• Obesity
• Polycythemia vera
• Idiopathic hyperkinetic heart syndrome
Kidney disease: Acute nephritis, or chronic kidney insufficiency
Carcinoid syndrome
Polyostotic fibrous dysplasia
Pulse of small volume (Hypokinetic or weak pulse):
Decreased cardiac output
CHF, acute myocardial infarction, states of shock, cardiac tamponade, constrictive pericarditis, myocarditis, cardiomyopathy
Peripheral vasoconstriction
Shock, hypovolemia
Mechanical obstruction
Mitral stenosis, aortic stenosis, HOCM, coarctation of aorta

TABLE 4.11: Causes of unilateral or bilateral weakness of radial pulse.

• Ectopic origin and aberrant course of the left subclavian artery
• Proximal compression
– Aneurysm of aorta
– Mediastinal growth
– Cervical rib
– Scalenus anterior syndrome
• Pulseless disease (Takayasu Arteritis)
• Peripheral embolism
• Coarctation of aorta
• In elderly
– Dissection of the aorta
– Aortitis
– Trauma (including iatrogenic)
– Embolism
– Arteriosclerotic obstruction

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- **Character or quality of pulse**
  - ***Small weak pulse:*** Often found in conditions with low stroke volume of left ventricle, narrow pulse pressure and increased peripheral resistance, e.g., left ventricular failure, diffuse myocardial disease, constrictive pericarditis, stenosis of mitral, pulmonary or tricuspid valve. A small, weak pulse at rapid rate (thready pulse) in states of shock.
  - ***Large bounding pulse (collapsing pulse):*** Suggests a high pressure associated with an increased flow and is seen in hyperkinetic circulatory states. A very large, bounding pulse of the *water hammer or collapsing* variety is usually associated with an increased stroke volume of LV, a wide pulse pressure and a decrease in peripheral resistance. The pulse strikes the palpating finger with a rapid forceful jerk and quickly disappears. It is described as having a *water hammer quality* because of its sudden impact and a collapsing quality because it falls away so rapidly due to peripheral vasodilation.

  The collapsing pulse is caused by the artery suddenly emptying as some of the blood flows back from the aorta into the ventricle and may occur in any condition with a large pulse pressure and low diastolic pressure. It indicates a low filling resistance in the reservoir into which the left ventricle pumps its contents. Causes are listed in **Table 4.12**.

Twice Beating Pulse

Dicrotic pulse: The double beat is produced during diastole by an accentuated, palpable dicrotic wave and is likely to be present when peripheral resistance and diastolic pressure are low as in fevers. Aortic regurgitation, mild or moderate dilated cardiomyopathy, severe dehydration, LVF, cardiac tamponade, advanced CHF.

Anacrotic pulse: Rarely the anacrotic notch in severe aortic stenosis may be so marked that it is possible to feel the initial portion of the pulse wave and the main wave as separate waves. This is usually felt in the carotid artery. It may also occur in low output states.

TABLE 4.12: Causes of bounding or water-hammer pulse.

- *Aortic run off into heart* – Aortic regurgitation, rupture of sinus of Valsalva into a cardiac chamber
- *Aortic run off into pulmonary arteries* – PDA, aortopulmonary window
- *Aortic run off into peripheral vessels*
- *Physiological* – Hot bath, alcohol, pregnancy
- *High output states* – Anemia, thyrotoxicosis, beriberi, anoxic cor pulmonale, liver cirrhosis
- *Arteriovenous fistulae* – Vascular malformations, trauma, Paget's disease
- *Extreme bradycardia* – A-V block

Pulsus bisferiens: The first systolic peak of the pulse (percussion wave P) is followed by second late positive pulse wave (tidal wave T). Found in presence of:

- Combination of moderate AS and severe AR.
- Severe hypertrophic obstructive cardiomyopathy.

Pulsus parvus et tardus: Small volume pulse (parvus) that rises slowly (tardus) to a late systolic peak due to mechanical obstruction to LV ejection in moderate to severe valvular aortic stenosis. It may be possible to palpate an anacrotic notch on the upstroke of the (carotid) pulse.

Pulsus alternans: There is beat to beat variability in the pulse amplitude. It has been attributed to cyclic changes in intracellular calcium and action potential duration. This pulse occurs in severe heart failure, severe aortic regurgitation, hypotension and hypovolemic conditions.

Pulsus bigeminus (coupling): Recurrent grouping of the heart beats in pairs followed by a pause.

Causes:

- Ectopic beats.
- Atrioventricular block, every third sinus impulse being blocked.
- Sinoatrial block with ventricular escape.
- Block in atrial flutter alternating between 2:1, 3:1 or 4:1.

Pulsus paradoxus: This is defined as fall in systolic pressure of more than 10 mm Hg with inspiration. In normal persons the systolic blood pressure may decline 3–10 mm Hg during inspiration, so that pulsus paradoxus is exaggeration of a normal phenomenon. Although inspiration increases venous return to the right side of the heart, there is relative pooling of blood in pulmonary vasculature as a result of lung expansion and more negative intrathoracic pressure during the active phase of respiration. The net result is a decrease in return of blood to LA and LV and subsequent fall in LV output and decrease in arterial pressure. When the systolic blood pressure falls *more than 10 mm Hg* the pulse is referred to as pulsus paradoxus. The phenomenon gets exaggerated whenever there is pericardial tamponade or severe pulmonary disease. The paradox in the pulse is that heart sounds are still audible at a time when no radial pulse is felt. The conditions where pulsus paradoxus can be seen are – pericardial tamponade, pulmonary embolism, severe obstructive lung disease, tension pneumothorax and morbid obesity.

CARDIAC ARRHYTHMIAS

The arrhythmias can be divided into two groups brady-arrhythmia and tachyarrhythmia, based on ventricular rate. The bradyarrhythmia can occur due to abnormality at SA node or AV node. The tachyarrhythmia can be supraventricular or ventricular origin.

Table 4.13 gives classification of arrhythmias according to the site of origin.

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TABLE 4.13: Classification of arrhythmias according to the site of origin.

Sinoatrial node
• Sinus bradycardia
• Sinus tachycardia
• Sinus arrhythmia
• Sinus arrest or block
• Wandering pacemaker
• Sinus extrasystoles
Atria
• Premature atrial contractions
• Atrial tachycardia
• Atrial flutter and fibrillation
• Chaotic atrial rhythm (multifocal atrial tachycardia)
• Atrial standstill
Atrioventricular junction
• A-V junctional premature beats
• A-V junctional tachycardia
• A-V junctional rhythm
• Heart block
Ventricles
• Ventricular premature contractions
• Ventricular tachycardia
• Bundle branch block
• Ventricular flutter and fibrillation
• Ventricular standstill

MECHANISMS

- **Automaticity:** An abnormal pacemaker overrides the normal pacemaker function at the SA node.
- **Re-entry:** Re-entry arrhythmias are circular movements of electrical depolarization within cardiac tissue. Re-entry requires the presence of two electrophysiologically different pathways around an insulated core (e.g., the AV valve annulus).
- **Trigger activity:** It is dependent on previous action potential when oscillations in the membrane depolarize the cell to threshold.

ANTIARRHYTHMIC DRUGS

Table 4.14 gives classification of antiarrhythmic drugs and their actions.

DISTURBANCES OF IMPULSE FORMATION AND CONDUCTION

Sinus bradycardia: Sinus rhythm slower than 60 beats per minute **(Table 4.15) (Fig. 4.6)**.

Sinus tachycardia: Sinus rhythm faster than 100 beats per minute **(Table 4.16) (Fig. 4.7)**.

Sinus Arrhythmia

The heart rate increases on inspiration and slows at the height of inspiration and during expiration **(Fig. 4.8)**. Phasic variation is more than 10%. When the breath is held the arrhythmia disappears. It is a normal phenomenon and depends on the respiratory variations in vagal tone inhibiting

TABLE 4.14: Classification of antiarrhythmic drugs and their actions.

Drug	*Dosage*	*Indications*	*Toxic effects*
Class I: *Sodium block*			
IA: Membrane stabilizing agents			
Quinidine	200–400 mg q6h	Vent. arrhy. VPCs, VT	GI disturbances Cinchonism Widening of QRS
Procainamide	PO 250–1,000 mg q3h IV 20 mg/min for 30–40 min	Junct. arrhy. Ectopics, tachy.	GI disturbances Hypotension after IV Lupus syndrome
Disopyramide	100–200 mg q6–8h	Supravent arrhy. APCs, PAT, AF, A flutter	Xerostomia Urinary retention Hypotension QRS prolonged
IB: Effect on vent. Refractoriness			
Lidocaine	Bolus 75 mg, then 50 mg q5 min to total 225 mg	Ventricular arrhythmias	CNS: Lightheadedness, confusion, dizziness, tinnitus CVS: Bradycardia, hypotension
Mexiletine	200–400 mg q8h	Ventricular arrhythmias	GI: Nausea, vomiting CNS: Dizziness, lightheadedness, tremor
Phenytoin	250 mg in normal saline over 10 min, then 100 mg q5 min as needed	Digoxin toxicity arrhythmias	Nystagmus, ataxia, slurred speech, confusion, dizziness

Contd...

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GOLWALLA'S MEDICINE FOR STUDENTS

Golwalla's Medicine for Students serves as a standard text for undergraduates, physicians, and as a quick and ready reckoner for PGs and practitioners across diverse disciplines. It provides nuggets of information in an easily assimilable form, which has considerable recall value.

The textbook is in a format which is easy on the eye and the mind, with excellent cross-referencing and updated medical information. The book is a one-stop location for most topics across subspecialties of medicine.

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Vivek Hande MD (Med) DNB (Gastroenterology) MPhil is one of the foremost Physicians and Gastroenterologists of the Armed Forces Medical Services. He did his MD in Internal Medicine and subsequently his DNB in Gastroenterology. He has nearly four decades of experience in Clinical Medicine. He has served in service hospitals across the length and breadth of the country and has a rich experience as a clinician, academician, teacher, mentor, researcher, and author. His advice to generations of medical students—undergraduates and postgraduates—has always been: "The patient is always right."

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