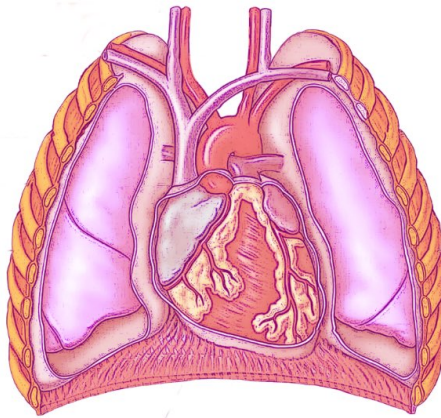




# Internal Medicine



Topic : Heart Failure Notes  
Done by : Johainah Taha

# Heart Failure (HF)

## Definition

Heart failure (HF) is a complex clinical **syndrome** where the heart fails to maintain normal **cardiac output** due to structural or functional cardiac disorders.

**Causes of HF:**

- Ischemia (MI) → systolic heart failure → ↓ contractility
- Hypertension → Diastolic heart failure → ↓ diastolic volume, poor filling
- Arrhythmias
- Volume overload → systolic overload
- Endocarditis / myocarditis
- High metabolic demand
- Failure of contractility

## Epidemiology

| Statistic                  | Details                                                                                                       |
|----------------------------|---------------------------------------------------------------------------------------------------------------|
| <b>Global Incidence</b>    | 2 per 1,000 individuals                                                                                       |
| <b>Age-Related Risk</b>    | Increases to <b>90 per 1,000</b> after age 85                                                                 |
| <b>Mortality Rate</b>      | 51.5% of HF patients die within 5 years (higher than cancer-related deaths)                                   |
| <b>Hospital Admissions</b> | - 5% of total hospital admissions are due to HF -<br><b>Most common cause of hospitalization after age 65</b> |
| <b>Prognosis</b>           | Frequent hospital admissions indicate a <b>poor prognosis</b>                                                 |
| <b>Economic Burden</b>     | HF treatment costs the UK <b>&gt;1 billion dollars per year</b>                                               |

## Pathophysiology of Heart Failure

### 1 Starling's Law: The Role of Preload

- Preload = The volume of blood & pressure in the ventricle at the end of diastole. (before contraction)
- How It Works:
- Increased venous return → Stretches myocardial fibers
- Enhances ventricular contraction → Increases CO
- However, excessive stretching leads to reduced contractility, causing **HF** and **pulmonary edema** (fluid accumulation in lungs) → Leads to **SOB**

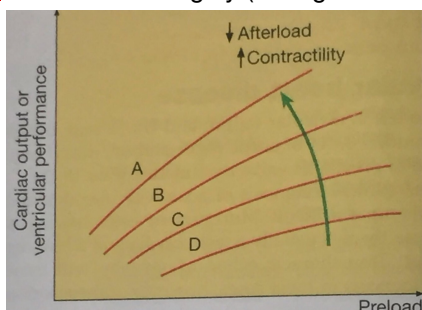
Example: If you keep filling a balloon with water, it will expand at first, but if it becomes overfilled, it will burst or stop working efficiently.

### 2 Laplace's Law: The Role of Afterload

- Afterload = The resistance the ventricle must overcome to eject blood (blood volume and pressure in the ventricle during systole).  
HTN, aortic stenosis → ↑ afterload → the heart work harder → LVH, Dilatation, Failure
- Myocardial wall tension depends on:
- Intraventricular pressure (P) × Ventricular radius (R)
- Increased afterload → LV End-Diastolic Volume (LVEDV) rises → Ventricular dilatation → Cardiomegaly (enlarged heart)

- The heart compensates by increasing CO, but at the cost of progressive LV dilatation.

Example: Imagine lifting heavy weights every day → Your muscles get tired → Eventually, they fail



## Main Mechanisms of Heart Failure

| Mechanism                                           | Causes                                                                                                                                                                                                                                                                    |
|-----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. Reduced Ventricular Contractility</b>         | Ischemic Heart Disease (IHD), Myocardial Infarction (MI)                                                                                                                                                                                                                  |
| <b>2. Ventricular Pressure Overload (Afterload)</b> | - <b>Left Ventricle (LV):</b> Hypertension, Aortic Stenosis (calcific or bicuspid), Hypertrophic Cardiomyopathy (HOCM), Congenital Subaortic Membrane, Coarctation of Aorta - <b>Right Ventricle (RV):</b> Pulmonary Stenosis, Pulmonary Embolism, Pulmonary Hypertension |
| <b>3. Ventricular Inflow Obstruction (Preload)</b>  | Mitral Valve Stenosis (MVS), Tricuspid Valve Stenosis (TVS)                                                                                                                                                                                                               |
| <b>4. Ventricular Volume Overload</b>               | Aortic Regurgitation (AI), Pulmonary Regurgitation (PI), Mitral Valve Regurgitation (MVR), Tricuspid Valve Regurgitation (TVR), Atrioventricular Shunts (VSD, ASD, PDA)                                                                                                   |
| <b>5. High Metabolic Demand</b>                     | <b>Tachycardia</b> , <b>Hyperthyroidism</b> (Thyrotoxicosis), <b>Anemia</b> , <b>Paget's Disease</b> → ↑ osteoclast activity in skull, spine, pelvis                                                                                                                      |
| <b>6. Arrhythmias</b>                               | arrhythmia does not give adequate time for good ventricular filling so will reduce cardiac output<br><br>- <b>Tachyarrhythmias:</b> Atrial Fibrillation (AF), Supraventricular Tachycardia (SVT) - <b>Bradyarrhythmias:</b> Complete Heart Block, Sick Sinus Syndrome     |
| <b>7. Impaired Ventricular Diastolic Filling</b>    | Pericardial diseases (Tamponade, Constrictive Pericarditis), Restrictive Cardiomyopathy (Amyloidosis, Hemochromatosis)                                                                                                                                                    |
| <b>8. Toxic Causes</b>                              | Alcoholic Cardiomyopathy, Chemotherapy (Doxorubicin)                                                                                                                                                                                                                      |
| <b>9. Infections</b>                                | Myocarditis, Subacute Bacterial Endocarditis (SBE), Sarcoidosis, Chagas Disease                                                                                                                                                                                           |
| <b>10. Systemic Diseases</b>                        | Chronic Kidney Disease (CKD) (Cardiorenal Syndrome), Diabetes (Diabetic Cardiomyopathy)                                                                                                                                                                                   |

# Primary Cardiac Abnormalities in Heart Failure (HF)

## 1 Ventricular Function Impairment

### • Causes:

- Myocardial cell loss (apoptosis, necrosis)
- Myocardial hyaline deposition and fibrosis
- Cytokine release and free radicals  
→ Leads to low cardiac output and hypotension
- Neurohormonal activation as a compensatory mechanism <sup>with time they make the situation worse</sup> (The vicious cycle)

| System                                                                                                                                                                                                   | Effects                                                                                                                                                                                                              | Consequences                                                                                                                              |                                                                                                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. Sympathetic Nervous System Activation</b><br><i>* Short-term fix.</i><br><i>* Long-term damage.</i>                                                                                                | <sup>↓ CO</sup><br><b>- Noradrenaline release</b> -<br>① <b>Tachycardia</b> -<br>② <b>Vasoconstriction</b> -<br>③ <b>Increased renin release</b> →<br><b>Higher BP &amp; afterload</b>                               | - Increased myocardial workload → More myocardial damage & loss - Further reduction in <b>cardiac output</b> → <b>Vicious cycle</b>       | Example: If your phone battery is low, you increase brightness and use power-draining apps to make up for it. This drains the battery even faster! |
| <b>2. Renin-Angiotensin-Aldosterone System (RAAS) Activation</b><br><sup>↓ BP → Renin from Kidney</sup><br><i>Angiotensinogen → Ang I → Ang II</i> <sup>↑ Vasoconstriction</sup><br><i>↑ Aldosterone</i> | - Sodium & water retention - Increased <b>intravascular volume</b> - Increased <b>BP</b> -<br><b>Increased preload &amp; afterload</b>                                                                               | - More myocardial damage & loss - Further <b>decreased cardiac output</b> → <b>Vicious cycle</b>                                          | Example: If a pipe is blocked, adding more water pressure (fluid retention) will only make the blockage worse                                      |
| <b>3. High BNP/ANP Levels</b><br><i>Brain Natriuretic Peptide</i> <i>Atrial Natriuretic Peptide</i>                                                                                                      | - Secreted due to <b>stretching of volume receptors</b> in ventricles & atria - <b>Effects:</b><br><b>Natriuresis &amp; vasodilation</b><br><sup>Releasing H<sub>2</sub>O &amp; water in urine</sup> <sup>↓ BP</sup> | <b>- Diagnostic marker for HF:</b><br><b>- NT-proBNP &gt;300 pg/mL</b> in sinus rhythm - <b>&gt;900 pg/mL</b> in atrial fibrillation (AF) | Example: Think of a car overheating—BNP is like a warning light telling you something is wrong.                                                    |
| <b>4. Antidiuretic Hormone (ADH) Activation</b><br><sup>→ Vasopressin</sup>                                                                                                                              | <b>- Vasopressin secretion</b> -<br>Water retention<br><sup>→ ↑ fluid &amp; vol load</sup>                                                                                                                           | <b>- Syndrome of Inappropriate ADH Secretion (SIADH)</b> → Leads to <b>hyponatremia in severe HF</b> (poor prognosis)                     | Example: If a sponge is already full of water, adding more water will just spill over and cause problems.                                          |

## Classification of Heart Failure (HF) according to EF

| Type                                            | Ejection Fraction (EF) | Characteristics                                                                                                                                                                                                                                                                                                                                      |                                                                     |
|-------------------------------------------------|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| <b>Normal EF</b>                                | <b>52%-55%</b>         | No heart failure                                                                                                                                                                                                                                                                                                                                     |                                                                     |
| <b>HFrEF (Heart Failure with Reduced EF)</b>    | <b>&lt;40%</b>         | <b>Systolic HF</b> – Impaired contraction                                                                                                                                                                                                                                                                                                            | <sup>Causes in</sup><br>→ ① MI<br>② IHD<br>③ Dilated cardiomyopathy |
| <b>HFpEF (Heart Failure with Preserved EF)</b>  | <b>≥50%</b>            | <b>Diastolic HF</b> – Normal EF but <u>impaired LV filling</u> due to <b>fibrosis &amp; stiffness</b> -<br><sup>→ myocardial inflammation</sup><br><b>Common Causes:</b> Insulin resistance, Obesity, Diabetes + HTN + Hypertrophic cardiomyopathy + Amyloidosis + Hemochromatosis.<br><b>- No specific treatment, only manage underlying causes</b> |                                                                     |
| <b>HFmrEF (Heart Failure with Mid-Range EF)</b> | <b>40% - &lt;55%</b>   | <b>Intermediate category</b>                                                                                                                                                                                                                                                                                                                         |                                                                     |
| <b>HF-IM-EF</b>                                 |                        |                                                                                                                                                                                                                                                                                                                                                      |                                                                     |

## Types of Heart Failure Based on Clinical Features

| Type                       | Clinical Features                                                                                                                                  |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. <b>Left-Sided HF</b>    | <b>Pulmonary</b> congestion →<br><b>Shortness of breath (SOB)</b> , <b>Paroxysmal Nocturnal Dyspnea (PND)</b> , <b>Pulmonary edema</b>             |
| 2. <b>Right-Sided HF</b>   | <b>Systemic</b> congestion →<br><b>Leg edema, Ascites, Anasarca, High JVP</b>                                                                      |
| 3. <b>Biventricular HF</b> | <b>Congestive heart failure</b> –<br>Involves both left & right HF symptoms                                                                        |
| 4. <b>High-Output HF</b>   | Increased cardiac demand due to <b>Thyrotoxicosis, Anemia, Beriberi</b> <small>→ Vitamin (B1) affecting CNS + NIS described to dry and wet</small> |
| 5. <b>Chronic HF</b>       | Compensated or Decompensated                                                                                                                       |
| 6. <b>Acute HF</b>         | <b>Sudden worsening</b> with pulmonary edema                                                                                                       |

## Causes of acute HF

| Acute HF Causes                                     | Examples                                                                                                               |
|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| <b>Acute Pulmonary Edema</b>                        | Fluid overload in lungs                                                                                                |
| <b>Acute Myocardial Infarction (MI)</b>             | Sudden cardiac ischemia                                                                                                |
| <b>Acute Infective Endocarditis</b>                 | Valve infection                                                                                                        |
| <b>Acute Valvular Destruction</b>                   | Severe valve regurgitation                                                                                             |
| <b>Acute Rupture of Chordae Tendineae</b>           | - Leads to <b>Mitral Regurgitation (MR)</b> -<br>Common in <b>Mitral Valve Prolapse (MVP)</b> , <b>Marfan Syndrome</b> |
| <b>Acute Myocarditis (Viral)</b>                    | Viral infection of myocardium                                                                                          |
| <b>Severe Accelerated or Malignant Hypertension</b> | Uncontrolled high BP leading to HF                                                                                     |
| <b>Acute Dissecting Aortic Aneurysm</b>             | Life-threatening vascular emergency                                                                                    |

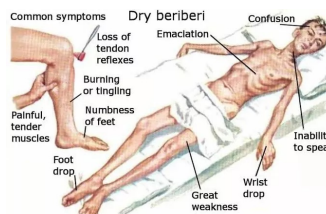
## 7. Acute on chronic HF (decompensated HF)

| Causes                        | Triggers of Decompensated HF                                                                                                                                                                                                   |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cardiac Causes</b>         | - <b>Poor drug compliance</b> -<br>Uncontrolled <b>HTN, DM</b> -<br>Acute Coronary Syndrome ( <b>ACS, IHD</b> ) - <b>Acute MR</b> due to papillary muscle dysfunction - <b>New-onset arrhythmia</b> (Atrial Fibrillation - AF) |
| <b>Systemic Causes</b>        | - <b>Infection/Sepsis</b> -<br><b>Anemia</b> - <b>Thyroid dysfunction</b> (Hyperthyroidism/Hypothyroidism)                                                                                                                     |
| <b>Electrolyte Imbalances</b> | - <b>Potassium (K+), Magnesium (Mg2+), Calcium (Ca2+), Phosphate (Phos)</b>                                                                                                                                                    |
| <b>Thromboembolic Events</b>  | - <b>Acute Pulmonary Embolism</b>                                                                                                                                                                                              |

more details

Beri Beri:

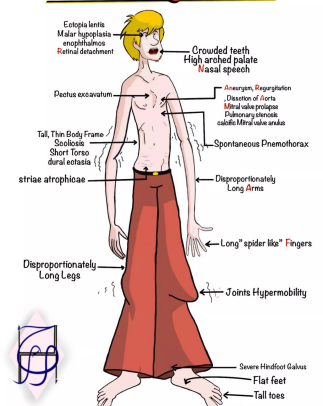
### Beriberi Disease



Marfan Syndrome:



### Marfan Syndrome



# New York Heart Association (NYHA) Classification of Heart Failure (HF)

## 1 NYHA Classification of HF:

| Class            | Limitation of Physical Activity | Symptoms                                                                     |
|------------------|---------------------------------|------------------------------------------------------------------------------|
| <b>Class I</b>   | No limitation                   | No symptoms with ordinary physical activity                                  |
| <b>Class II</b>  | Mild limitation                 | Symptoms with moderate physical activity <i>(Symptoms on exertion)</i>       |
| <b>Class III</b> | Moderate limitation             | Symptoms with mild physical activity <i>(Symptoms with minimal exertion)</i> |
| <b>Class IV</b>  | Severe limitation               | Symptoms at rest (orthopnea, PND, pulmonary edema)                           |

## 2 New HF Classification

| Stage                  | Definition                                                                                            |
|------------------------|-------------------------------------------------------------------------------------------------------|
| <b>Pre-HF</b>          | <b>Risk factors</b> present + Structural or functional heart <b>abnormalities</b> but no symptoms yet |
| <b>Asymptomatic HF</b> | Structural heart disease present but no symptoms                                                      |
| <b>Symptomatic HF</b>  | Symptoms of HF present with physical activity                                                         |
| <b>Advanced HF</b>     | Severe symptoms at rest with significant limitation of daily activities                               |

## 3 Pathophysiology of HF Progression

| Class                             | Cardiac Dysfunction         | Compensation Mechanisms                                                                                                                                                                                                                              |
|-----------------------------------|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Class I &amp; II (Mild HF)</b> | Mild cardiac dysfunction    | Cardiac output is <b>maintained</b> by: ✓<br>Increased venous return ✓<br>Increased diastolic ventricular filling pressure ✓<br>Increased heart rate                                                                                                 |
| <b>Class III (Severe HF)</b>      | Severe cardiac dysfunction  | Cardiac output is <b>only maintained</b> by: ✓<br>Significant sinus tachycardia ✓<br>Increased venous return (causing pulmonary interstitial & alveolar fluid accumulation) ✓<br>Shortness of breath (SOB) with mild exertion but <b>not at rest</b> |
| <b>Class IV (Very Severe HF)</b>  | Extreme cardiac dysfunction | <b>Severely depressed cardiac output at rest</b> despite: ✓ High venous return & pressure ✓ High heart rate (tachycardia) ✓<br>SOB at rest, <b>orthopnea</b> , <b>acute pulmonary edema</b>                                                          |

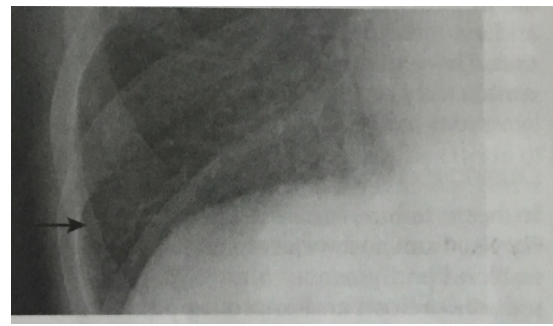
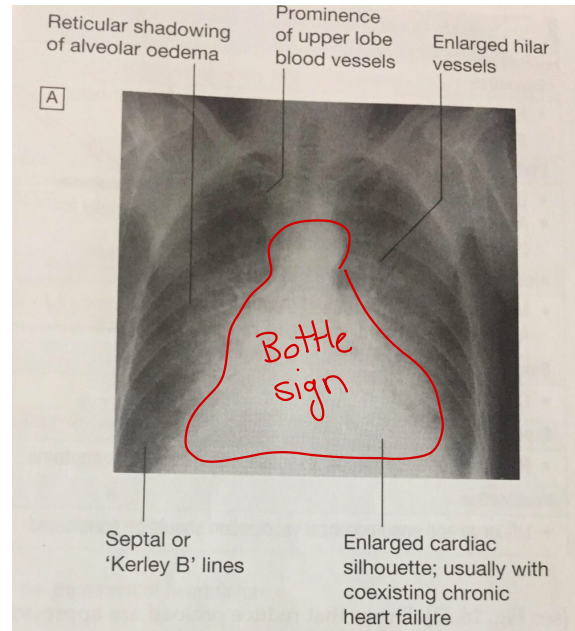
## Symptoms & Signs of HF

### Symptoms

| Symptom                          | Description                                                                                                                                                                  |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Shortness of Breath (SOB)</b> | - On exertion → <b>Early symptom</b> of HF<br>- At rest (orthopnea) → <b>Severe HF</b><br>- During sleep (Paroxysmal Nocturnal Dyspnea, PND) → <b>Sign of fluid overload</b> |
| <b>Fatigue &amp; Pallor</b>      | Due to <b>low cardiac output</b> — blood flow is maintained only to <b>vital organs</b> (brain, kidneys) at the expense of muscles and skin.                                 |

## Signs of HF

| Sign                                          | Description                                                                                                                                                                            |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Elevated Jugular Venous Pressure (JVP)</b> | Due to <b>right-sided heart failure</b>                                                                                                                                                |
| <b>Cyanosis</b>                               | <b>Central &amp; peripheral</b> cyanosis due to <b>poor oxygenation</b>                                                                                                                |
| <b>Edema</b>                                  | <b>Bilateral ankle edema, ascites, anasarca</b> (severe fluid retention)                                                                                                               |
| <b>Hypotension &amp; Dizziness</b>            | Due to reduced cardiac output                                                                                                                                                          |
| <b>Arrhythmias</b>                            | <b>Tachycardia:</b> Sinus tachycardia, atrial flutter, AF, VT, VF → Can cause sudden cardiac arrest & death.<br><b>Bradycardia:</b> Complete heart block (can lead to cardiac arrest). |
| <b>Heart Sounds</b>                           | <b>3rd &amp; 4th heart sounds (gallop rhythm), systolic murmur (mitral regurgitation)</b>                                                                                              |
| <b>Pulmonary Signs</b>                        | <b>Bilateral lung basal crackles</b> (fluid overload)                                                                                                                                  |
| <b>Liver Congestion</b>                       | <b>Tender hepatomegaly, congested liver, jaundice</b>                                                                                                                                  |
| <b>Weight Loss &amp; Cachexia</b>             | <b>Cardiac cachexia</b> (severe weight loss due to chronic HF)                                                                                                                         |
| <b>Chest X-ray Findings</b>                   | <b>Cardiomegaly, pleural effusion, pulmonary edema</b>                                                                                                                                 |



### \*The effect of HF:

↓ CO → organ hypoperfusion → Fatigue, kidney dysfunction.

Fluid overload → Edema → Pulmonary edema, peripheral edema, Ascites

**Left sided HF** → pulmonary congestion

1. Dyspnea
2. Orthopnea
3. PND
4. Crackles in lung

**Right sided HF** → Systemic congestion.

1. ↑ JVP.
2. peripheral edema.
3. hepatomegaly.
4. Ascites.

### Investigations in HF:

1. BNP or NT-proBNP
2. Echocardiography
3. Chest x-ray
4. ECG
5. Blood tests → Renal function, Electrolytes, Liver function, Thyroid function.

## Management of HF:

• Lifestyle modifications → Low salt diet, fluid restriction, weight monitoring.

• Medications:

• Diuretics → Reduce congestion (e.g., furosemide).

• ACE inhibitors/ARBs → Reduce afterload.

• Beta-blockers → Reduce mortality (e.g., carvedilol, bisoprolol).

• Mineralocorticoid receptor antagonists (MRAs) → Spironolactone.

• SGLT2 inhibitors → Newer HF treatment (dapagliflozin).

• Devices:

• ICD (Implantable Cardioverter Defibrillator) in severe HFrEF.

• CRT (Cardiac Resynchronization Therapy) in dyssynchronous HF.

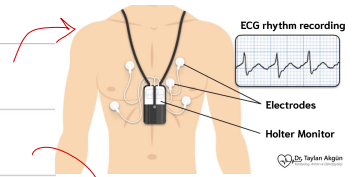
# Myocardial Remodeling in HF

- Progressive **changes** in ventricular size, shape, and function due to **myocardial cell damage**.
- Leads to ventricular wall **thinning and dilatation**, ultimately progressing to heart failure.

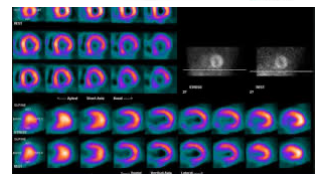
## Investigations for HF

| Investigation                  | Purpose                                                                                                                                                                                                                                                                                              |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Electrocardiogram (ECG)</b> | Detect arrhythmias, ischemic changes, or conduction abnormalities.                                                                                                                                                                                                                                   |
| <b>Chest X-ray (CXR)</b>       | Assess cardiomegaly, pulmonary congestion, and pleural effusion.                                                                                                                                                                                                                                     |
| <b>Blood tests</b>             | <ul style="list-style-type: none"><li>- <b>Cardiac enzymes:</b> To assess myocardial injury.</li><li>- <b>NT-proBNP:</b> &gt;300 pg/mL (sinus rhythm) or &gt;900 pg/mL (AF) suggests HF.</li><li>- <b>Other labs:</b> FBS, HbA1c, urea, creatinine, lipids, T3, T4, TSH, CBC, LFT, PT/INR.</li></ul> |
| <b>Echocardiography</b>        | Transthoracic or transesophageal; assesses cardiac function, valve status, and ejection fraction.                                                                                                                                                                                                    |

|                                         |                                                                                     |
|-----------------------------------------|-------------------------------------------------------------------------------------|
| <b>Holter monitoring (24-hour ECG)</b>  | Detects intermittent arrhythmias.                                                   |
| <b>Nuclear isotope cardiac study</b>    | Evaluates myocardial perfusion and function.                                        |
| <b>Cardiac catheterization</b>          | Diagnostic and therapeutic purposes (e.g., PCI, valvotomy, closure of VSD/ASD/PDA). |
| <b>Cardiac MRI &amp; CT angiography</b> | Provides detailed imaging of heart structures and vessels.                          |



The radiotracer, injected into a vein, emits gamma radiation as it decays. A gamma camera scans the radiation area and creates an image.



## Management of HF

- to reduce symptoms
- slow progression
- prevent complications.

### A. Lifestyle and Preventive Measures

- Lifestyle modification
- Influenza and COVID-19 vaccination
- Treat the underlying cause

### B. Pharmacological Treatment

ACEi, ARBs, Beta-blockers, SGLT2 inhibitors, Vasodilators, Diuretics, Mineralocorticoid receptor antagonists, Iron therapy

| Drug Class                                  | Examples                                                    | Mechanism                                                  |
|---------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|
| <b>Diuretics</b>                            | Furosemide, hydrochlorothiazide, spironolactone, eplerenone | Reduce fluid overload.                                     |
| <b>ACE inhibitors (ACEi)</b>                | Enalapril, lisinopril, ramipril                             | Reduce afterload and prevent remodeling.                   |
| <b>Angiotensin receptor blockers (ARBs)</b> | Valsartan, losartan, candesartan                            | Alternative to ACEi.                                       |
| <b>Beta-blockers</b>                        | Metoprolol, bisoprolol, nebivolol, carvedilol               | Reduce heart rate and myocardial oxygen demand.            |
| <b>SA node blockers</b>                     | Ivabradine                                                  | Lowers heart rate in patients intolerant to beta-blockers. |

|                                                          |                                             |                                        |
|----------------------------------------------------------|---------------------------------------------|----------------------------------------|
| <b>Cardiac glycosides</b>                                | Digoxin                                     | Used in HF with atrial fibrillation.   |
| <b>Vasodilators</b>                                      | Isosorbide dinitrate, hydralazine           | Reduce preload and afterload.          |
| <b>ARNI (Angiotensin receptor-neprilysin inhibitors)</b> | Sacubitril/valsartan (Entresto)             | Enhances natriuretic peptide function. |
| <b>SGLT2 inhibitors</b>                                  | Empagliflozin, dapagliflozin, canagliflozin | Improve cardiac and renal outcomes.    |
| <b>Iron therapy</b>                                      | IV iron for ferritin <100 ng/mL             | Treats anemia in HF.                   |

### C. Electrical Therapy.

| Intervention                                        | Purpose                                                                  |
|-----------------------------------------------------|--------------------------------------------------------------------------|
| <b>Implantable Cardioverter Defibrillator (ICD)</b> | Prevents sudden cardiac death in high-risk HF patients.                  |
| <b>Cardiac Resynchronization Therapy (CRT)</b>      | Improves ventricular synchronization in left bundle branch block (LBBB). |

### D. Mechanical Support & Surgical Management

| Intervention                                     | Purpose                                                             |
|--------------------------------------------------|---------------------------------------------------------------------|
| <b>Intra-aortic balloon pump (IABP)</b>          | Improves coronary blood flow in cardiogenic shock.                  |
| <b>Ventricular assist devices (VAD)</b>          | Bridge to heart transplant or destination therapy in refractory HF. |
| <b>Coronary artery bypass graft (CABG)</b>       | Treats ischemic HF.                                                 |
| <b>Mitral/aortic valve repair or replacement</b> | Manages valvular HF.                                                |
| <b>Heart transplant</b>                          | For end-stage HF refractory to medical therapy.                     |