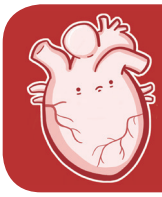

NOTES
HEART FAILURE

GENERALLY, WHAT IS IT?

PATHOLOGY & CAUSES

- A complex clinical syndrome characterized by the heart's inability to effectively fill and/or eject (pump) blood
- *Stroke volume (SV):* volume (mL) of blood pumped by heart per contraction
- *Cardiac output (CO):* volume of blood pumped by heart per minute (L/min)
  - CO = SV X heart rate
- *Preload:* amount of blood in left ventricle before contraction
- *Afterload:* stress on the ventricular wall during systole
  - ↑ systemic resistance, ↑ blood viscosity, aortic valve stenosis, ventricular dilation → ↑ afterload
- *Inotropy:* cardiac contractility
- *Ejection fraction (EF):* % of blood leaving heart during each contraction
  - $E = \left(\frac{stroke\ volume}{end\ diastolic\ volume} \right) \times 100$
- *Frank–Starling mechanism:* loading ventricle with blood during diastole, stretching out cardiac muscles → more forceful contraction; ↑ SV during systole

Heart failure (HF) with reduced ejection fraction (HFrEF)

- Systolic HF; "pump dysfunction"
- *Causes:* ↓ contractility/force of contraction (e.g. myocardial infarction, myocarditis), ↓ blood supply to the heart (e.g. coronary artery disease), ↑ afterload (e.g. hypertension), impaired mechanical function (e.g. valve disease)
- Normal preload, ↓ contractility (inotropy; force of contraction) → inadequate emptying of ventricles during systole → ↓ EF ≤ 40 (HFrEF); often also have some degree of diastolic dysfunction

HF with preserved ejection fraction (HFpEF)

- Diastolic HF; "filling dysfunction"
- *Causes:* restrictive cardiomyopathy (e.g. amyloidosis, sarcoidosis), valve disease, hypertension
- Ventricles noncompliant and unable to fill during diastole → ↑ filling pressures ↓ preload, normal contractility → ↓ SV → preserved EF ≥ 50 (HFpEF)

TYPES

- Biventricular heart failure
  - Left, right failure; systolic/diastolic
- Cor pulmonale
  - Heart failure secondary to any cause of pulmonary arterial hypertension
- Left-sided heart failure
  - Impaired ability of the left ventricle to maintain adequate cardiac output without an increase in left-sided filling pressures
- Right-sided heart failure
  - Impaired ability of the right ventricle to deliver of blood flow to the pulmonary circulation and ↑ right atrial pressure
- Classification based on structure and symptoms
  - ACC/AHA HF Stages, NYHA Classes (see table)

CLASSIFICATION OF HEART FAILURE

ACC/AHA HF STAGE	NYHA FUNCTIONAL CLASS
A. At risk for HF without structural heart disease or symptoms	
B. Structural heart disease but without HF	**I.** Asymptomatic
C. Structural heart disease with prior or current HF symptoms	**II.** Symptomatic with moderate exertion **III.** Symptomatic with minimal exertion
D. Refractory HF requiring advanced interventions (e.g. implantable cardioverter defibrillator, biventricular pacing, left ventricular assist device)	**IV.** Symptomatic at rest

ACC - American College of Cardiology
AHA - American Heart Association
NYHA - New York Hospital Association

RISK FACTORS

- *Cardiac disorders:* ischemic heart disease, valvular heart disease, hypertension, LV hypertrophy, peripartum cardiomyopathy, myocarditis, congenital heart disease, chronic tachyarrhythmias
- *Other chronic diseases:* hypertension, diabetes, obesity, chronic lung disease, infiltrative diseases (e.g. amyloidosis)
- *Toxins:* cigarette smoking, ethanol, cardiotoxic medications (e.g. doxorubicin, amphotericin B); illicit drugs (e.g. amphetamines, cocaine)
- *High-output states:* thyrotoxicosis, anemia
- ↑ age

COMPLICATIONS

- Cardiogenic shock
- Biventricular heart failure
  - Left/right-sided HF precursor/ complication of each other
- Arrhythmias
- End organ damage: due to lack of perfusion
- Liver damage (congestive hepatopathy)
- Exacerbation
  - See mnemonic
  - Certain drugs may exacerbate HF; e.g. NSAIDs, excessive doses of beta blockers, calcium channel blockers, cyclophosphamide

MNEMONIC: FAILURE

Exacerbation of Heart failure

Forgot medication
Arrhythmia/Anemia
Ischemia/Infarction/Infection
Lifestyle (e.g. too much salt)
Upregulation of CO (e.g. pregnancy, hyperthyroidism)
Renal failure
Embolism (e.g. pulmonary)

SIGNS & SYMPTOMS

- *High filling pressures:* pulmonary edema, dyspnea, orthopnea, exercise intolerance, paroxysmal nocturnal dyspnea (PND), basilar crackles, tachypnea, jugular venous distention (JVD), hypoxemia, fatigue, peripheral edema, hepatomegaly, S3
- *Low cardiac output:* tachycardia, hypotension, cool extremities, ↓ pulse pressure, ↓ urine output, ↓ appetite

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Detects cardiomegaly, chamber and vessel enlargement, pulmonary congestion, presence of pericardial and pleural effusions

Doppler echocardiography

- Evaluates hemodynamics related to in valvular and biventricular function

Right heart (pulmonary artery) catheterization

- Measures CO (cardiac index), filling pressures, pulmonary capillary wedge pressure (PCWP)

MRI

- Visualizes ventricular volumes, mass, presence of myocardial remodeling

LAB RESULTS

- ↑ B-type natriuretic peptide (BNP) and/or N-terminal pro-BNP
- ↑ serum creatinine and blood urea nitrogen (BUN) indicates glomerular filtration rate ↓ GFR due to hypoperfusion
- ↑ serum total bilirubin and aminotransferase indicates congestive hepatopathy from right-sided HF
- ↑ serum lactate if cardiogenic shock
- Exercise testing: six-minute walk test and/or a cardiopulmonary exercise test measuring oxygen uptake (Vo2) evaluates exercise capacity

OTHER DIAGNOSTICS

- History and physical examination identifying characteristic symptoms, evidence of fluid retention and/or hypoperfusion and functional impairment due to cardiac dysfunction

ECG

- Identifies contributing rhythm disturbances

ACUTE HEART FAILURE CLASSIFICATION

IS PERFUSION LOW?	IS CONGESTION PRESENT? NO	IS CONGESTION PRESENT? YES
NO	**Warm & Dry** (Compensated) PCWP normal CI normal	**Warm & Wet** (Congested) PCWP elevated CI normal
YES	**Cold & Dry** (Low flow state) PCWP low/normal CI decreased	**Cold & Wet** (Decompensated) PCWP elevated CI decreased

TREATMENT

MEDICATIONS

- Individualized in accordance with New York Heart Association (NYHA) class, EF, comorbidities
- Angiotensin converting enzyme (ACE) inhibitor or angiotensin II receptor blockers (ARB)
- Beta-blocker (carvedilol, bisoprolol, metoprolol ER)
- Aldosterone agonist
- Mineralocorticoid receptor antagonist (HFpEF)
- Acute decompensation
  - See mnemonic

MNEMONIC: POND

Acute decompensation

Position (upright) +/- positive pressure ventilation (e.g. BiPAP)

Oxygen

Nitrates

Diuretics

OTHER INTERVENTIONS

- Lifestyle modifications
  - Low dietary salt, exercise as tolerated, smoking cessation, minimize alcohol intake
- Ventricular assist device (VAD)
- Implanted defibrillator
- Biventricular pacemaker for resynchronization

SURGERY

- Heart transplant
  - Considered in NYHA class of III or IV despite maximized medical and resynchronization therapy

COR PULMONALE

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PATHOLOGY & CAUSES

- Right ventricular hypertrophy, dilation, and/or dysfunction due to pulmonary hypertension secondary to pulmonary disease (e.g. chronic obstructive pulmonary disease (COPD), pulmonary fibrosis), upper airway obstruction (e.g. obstructive sleep apnea, obesity-hypoventilation syndrome), or chest wall irregularities (e.g. kyphoscoliosis)
- Acute cor pulmonale develops in the setting of a sudden volume and/or pressure overload in the right side of the heart; e.g. massive pulmonary embolism
- ↑ pulmonary vascular resistance → ↑ pulmonary circuit afterload → ↑ right ventricular workload → right ventricular hypertrophy or dilatation → impaired right ventricular function and failure → ↑ right atrial pressure → fluid back-up into venous circulation → peripheral edema

RISK FACTORS

- Presence of parenchymal or vascular lung disease, chronic airway obstruction
- Smoking
- Recent surgery, hypercoagulable states (↑ risk of pulmonary embolism)

COMPLICATIONS

- RV failure
- Liver dysfunction

SIGNS & SYMPTOMS

- Dyspnea, chest pain, peripheral edema, jugular venous distension, hepatomegaly

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Visualizes right ventricular hypertrophy, distended pulmonary vasculature, pulmonary edema

Echocardiography

- Detects structural and functional changes of right ventricle; estimates right ventricular systolic pressures

MRI

- Visualizes right ventricular hypertrophy, right atrial enlargement, tricuspid valve dysfunction regurgitation, retrograde flow

Cardiac catheterization

- ↑ elevated central venous pressure, ↑ right ventricular, end-diastolic pressure, evidence of underlying pulmonary disease

TREATMENT

MEDICATIONS

- Supplemental oxygen
- Loop diuretic

SURGERY

- Heart-lung transplant for resistant cor pulmonale

OTHER INTERVENTIONS

- Treat underlying disease process
- Lifestyle
  - Low dietary salt, exercise as tolerated, smoking cessation

DIASTOLIC HEART FAILURE

osms.it/diastolic-heart-failure

PATHOLOGY & CAUSES

- A clinical syndrome characterized by failure of the heart to pump sufficient blood to meet the metabolic needs of the body due to ↓ ventricular filling
- HF with preserved ejection fraction (HFpEF)
- Filling dysfunction
  - Stiff, non-compliant ventricle → ↓ ventricular relaxation → ↑ end diastolic pressure → ↑ resistance to filling → ↓ preload → EF ≥ 50, ↓ SV, ↓ CO → pulmonary congestion

RISK FACTORS

- ↑ age, restrictive cardiomyopathy (e.g. amyloidosis, sarcoidosis); hypertrophic cardiomyopathy, long-standing hypertension, valve disease (especially aortic stenosis), CAD, diabetes, obesity

COMPLICATIONS

- Arrhythmias, pulmonary embolism, pulmonary hypertension, right ventricular failure

SIGNS & SYMPTOMS

- Fatigue, dyspnea, orthopnea, exercise intolerance, pulmonary rales, JVD

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Cardiomegaly; pulmonary vascular congestion; enlargement of right atrium, ventricle, and pulmonary arteries

Doppler echocardiography

- Altered mitral flow velocity, ↑ LVEDP, LV hypertrophy with concentric remodeling, LA enlargement, ↑ pulmonary artery systolic pressure (PASP)

LAB RESULTS

- ↑ BNP/NT-proBNP

TREATMENT

MEDICATIONS

Alleviation of symptoms

- Diuretics; antihypertensives
  - Beta blockers, ACE inhibitors, ARBs, aldosterone antagonists

OTHER INTERVENTIONS

- Manage contributing factors and associated conditions
- Lifestyle modifications
  - Smoking cessation, ↓ sodium intake, weight management, ↓ alcohol intake

LEFT HEART FAILURE

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PATHOLOGY & CAUSES

- A clinical syndrome due to an alteration of structure and/or function of the left ventricle (LV) resulting in ↓ cardiac output, pulmonary congestion, and ↓ peripheral perfusion
- Categorized according to left ventricular ejection fraction (LVEF)
  - *Systolic HF:* ↓ LVEF ≤40 percent (HFrEF)
  - *Diastolic HF:* preserved LVEF (HFpEF)
- ↓ cardiac output → backup of blood into left atrium → pulmonary circulation → ↑ pressure in pulmonary capillaries → pulmonary edema → ↓ gas exchange, dyspnea
- Neurohormonal compensatory mechanisms
  - RAAS and adrenergic activation → renal salt and water retention + vasoconstriction → ↑ contractility, ↑ circulating volume → ↑ CO, ↑ organ perfusion
  - *Adverse effects of compensation:* ↑ afterload, ↑ LV workload, LV remodeling
  - Natriuretic peptide secretion occurs in response to compensatory mechanisms and atrial stretch → diuresis, natriuresis, partial RAAS inhibition

RISK FACTORS

- Coronary artery disease, infiltrative disease (e.g. amyloidosis, hemochromatosis) → cardiomyopathy
- Hypertension, aortic stenosis → ↑ afterload
- Mitral or aortic regurgitation → ↑ preload
- Exposure to toxins → myocardial damage
- Arrhythmias → ↓ filling, ↓ ineffective contractions
- age > 60
- Obesity
- Diabetes mellitus/metabolic syndrome

COMPLICATIONS

- Pulmonary edema, pulmonary hemorrhage (congested capillaries burst), pleural effusion, renal insufficiency

SIGNS & SYMPTOMS

- Exertional dyspnea, orthopnea; (PND), pulmonary edema (frothy, pink-tinged sputum), bibasilar rales, cough, nocturia, restlessness, confusion. S3/S4

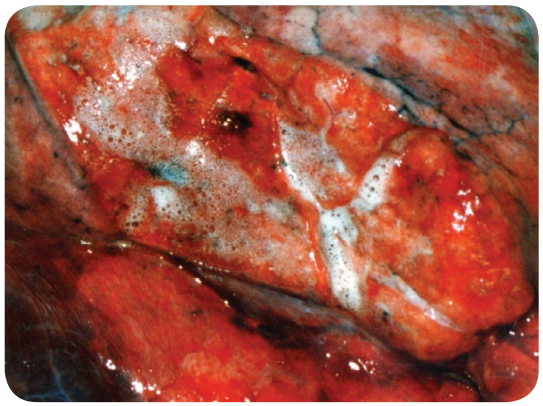

Figure 9.1 The gross pathological appearance of pulmonary edema. Exerting pressure on the lung parenchyma causes frothy white fluid to exude from it.

DIAGNOSIS

LAB RESULTS

- ↑ BNP/NT-proBNP

DIAGNOSTIC IMAGING

Chest X-ray

- Cardiomegaly, pulmonary vascular congestion, enlargement of right atrium, ventricle, and pulmonary arteries

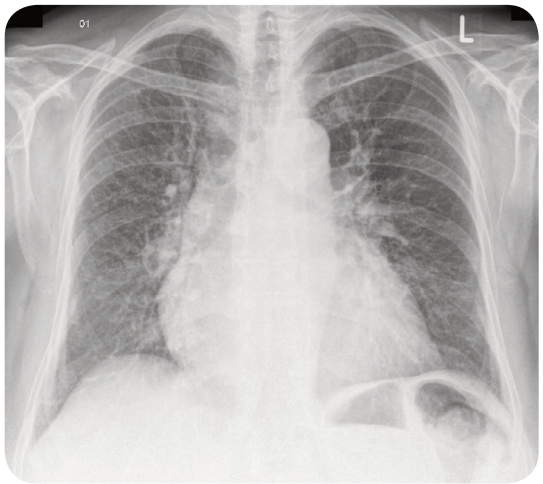

Figure 9.2 A plain chest X-ray image demonstrating pulmonary edema. The vessels at the hila are prominent and there are numerous Kerley B lines.

Echocardiography

- LV hypertrophy with eccentric remodeling, ↑ LVEDP, LA enlargement, ↑ PASP

OTHER DIAGNOSTICS

- ECG
  - Identifies contributing rhythm disturbances

TREATMENT

MEDICATIONS

- Diuretics, beta blockers, ACE inhibitors, ARBs, ARNI, hydralazine/nitrate combination, aldosterone antagonists
- Acute decompensation
  - See mnemonic

MNEMONIC: POND

Acute decompensation

Position (upright) +/- positive pressure ventilation (e.g. BiPAP)

Oxygen

Nitrates

Diuretics

MEDICATIONS

- Diuretics, beta blockers, ACE inhibitors, ARBs, ARNI, hydralazine/nitrate combination, aldosterone antagonists
- Acute decompensation
  - See mnemonic

SURGERY

- Heart transplant

OTHER INTERVENTIONS

- Manage contributing factors and associated conditions
- Lifestyle modifications: smoking cessation, ↓ sodium intake, weight management, ↓ alcohol intake
- Cardiac rehabilitation
- Implantable cardioverter-defibrillator (ICD)
- Ventricular assist device

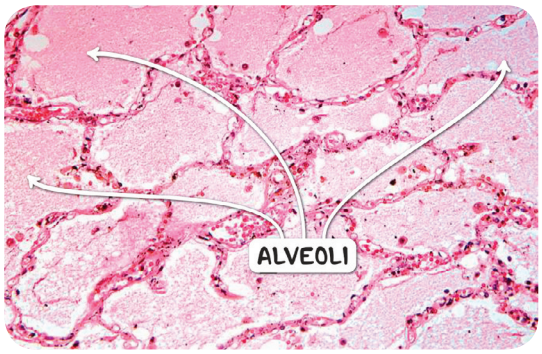

Figure 9.3 The histological appearance of pulmonary edema. There is flocculent fluid within the alveolar spaces.

Figure 9.4 Pitting edema in an individual with left-sided heart failure.

RIGHT HEART FAILURE

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PATHOLOGY & CAUSES

- A clinical syndrome due to an alteration of structure and/or function of the right ventricle (RV) leading to suboptimal delivery of blood flow to the pulmonary circulation and/or elevated venous pressures
- ↑ venous pressure → systolic volume overload
- ↑ RV workload (most often due to pulmonary congestion secondary to LV failure) → RV hypertrophy → ↓ pumping ability

CAUSES

- Left-sided heart failure, associated pulmonary edema (most common cause), right ventricular infarction, bacterial endocarditis, pulmonic valve stenosis, cardiomyopathy

COMPLICATIONS

- Eventual failure of left side of heart
- Tricuspid regurgitation
- Congestive hepatopathy
- Cardiac cachexia
  - Nausea, vomiting, anorexia, and diffuse abdominal pain due to abdominal venous congestion → weight loss

SIGNS & SYMPTOMS

- JVD, hepatojugular reflux, fatigue (related to poor gas exchange), exercise intolerance, peripheral edema, hepatosplenomegaly, ascites, S3/S4

DIAGNOSIS

DIAGNOSTIC IMAGING

Chest X-ray

- Cardiomegaly, pulmonary vascular congestion; enlargement of right atrium, ventricle, pulmonary arteries

Echocardiography
- Evaluates RV size and function; detects hemodynamic alterations

MRI
- Myocardial tissue, ventricular volume, muscle damage

Right heart catheterization
- ↑ pressure in heart chambers and lungs

LAB RESULTS
- ↑ BNP/NT-proBNP
- ↑ serum total bilirubin and aminotransferase indicates congestive hepatopathy

OTHER DIAGNOSTICS
- Clinical presentation: right heart dysfunction, rule out left heart dysfunction

ECG
- Identifies contributing rhythm disturbances

TREATMENT

MEDICATIONS
- Loop diuretics
  - Fluid management
- Vasopressors
  - Circulatory support

OTHER INTERVENTIONS
- Treat underlying condition

MNEMONIC: LMNOP
Treatment for Right heart failure

Lasix
Morphine
Nitrites
Oxygen
Vasso**P**ressors

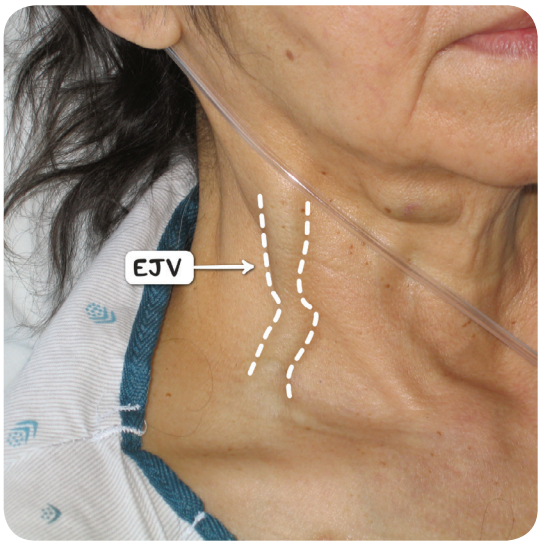

Figure 9.5 A distended external jugular vein (EJV) in an individual with right heart failure.

LEFT-SIDED VS. RIGHT-SIDED HEART FAILURE

LEFT	RIGHT
S_3	S_3
Pulmonary edema	Peripheral edema
Bilateral basilar rales	Hepatosplenomegaly
Orthopnea	Hepatojugular reflux
PND	JVD