Heart Failure Pathophysiology

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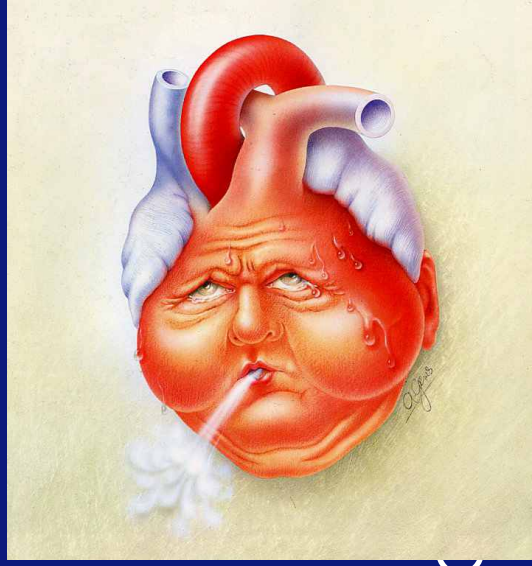
- ***Heart Failure-*** **Clinical syndrome … can result from any structural or functional cardiac disorder that impairs ability of ventricle to fill with or eject blood**

- Impact!
  - 5 million Americans- have heart failure
  - 500,000 new cases every year
  - 25-50 billion dollars a year to care for people with HF
  - 6,500,000 hospital days / year and 300,000 deaths/year
  - ***The most common reason for hospitalization in adults >65 years old.***

Heart Failure
Definition



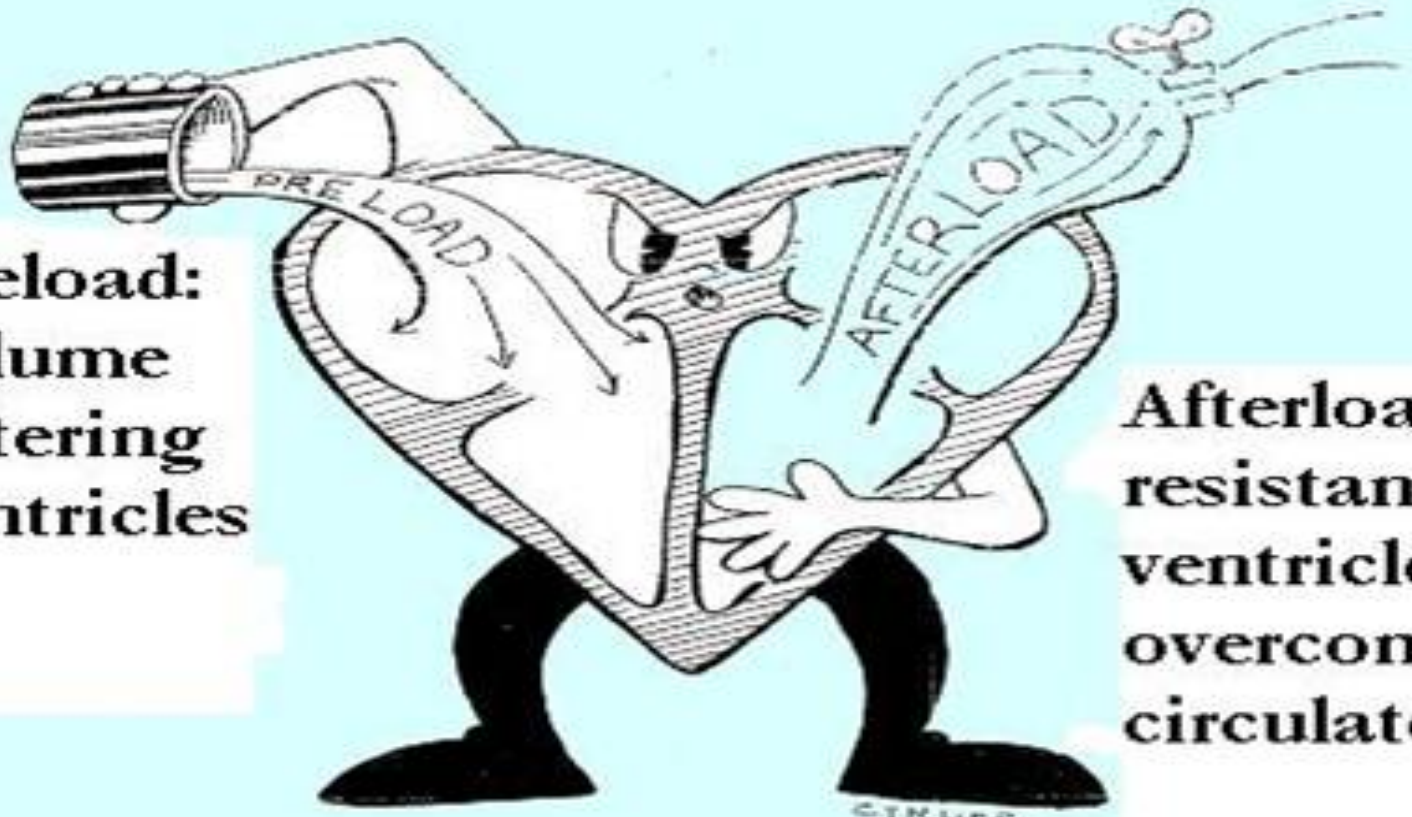
- It is the pathophysiological process in which the heart as a pump is unable to meet the metabolic requirements of the tissue for oxygen and substrates despite the venous return to heart is either normal or increased

Heart Failure

Key Concepts

- **Cardiac output (CO) = Stroke Volume (SV) x Heart Rate (HR)**
  - Becomes insufficient to meet metabolic needs of body
- SV – determined by preload, afterload and myocardial contractility
- Ejection Fraction (EF) (need to understand)
- Classifications HF
  - Systolic failure – decrease contractility
  - Diastolic failure – decrease filling
  - Mixed

Preload and Afterload



Preload: volume entering ventricles

Afterload: resistance left ventricle must overcome to circulate blood

Factors Effecting Heart Pump Effectiveness

Preload

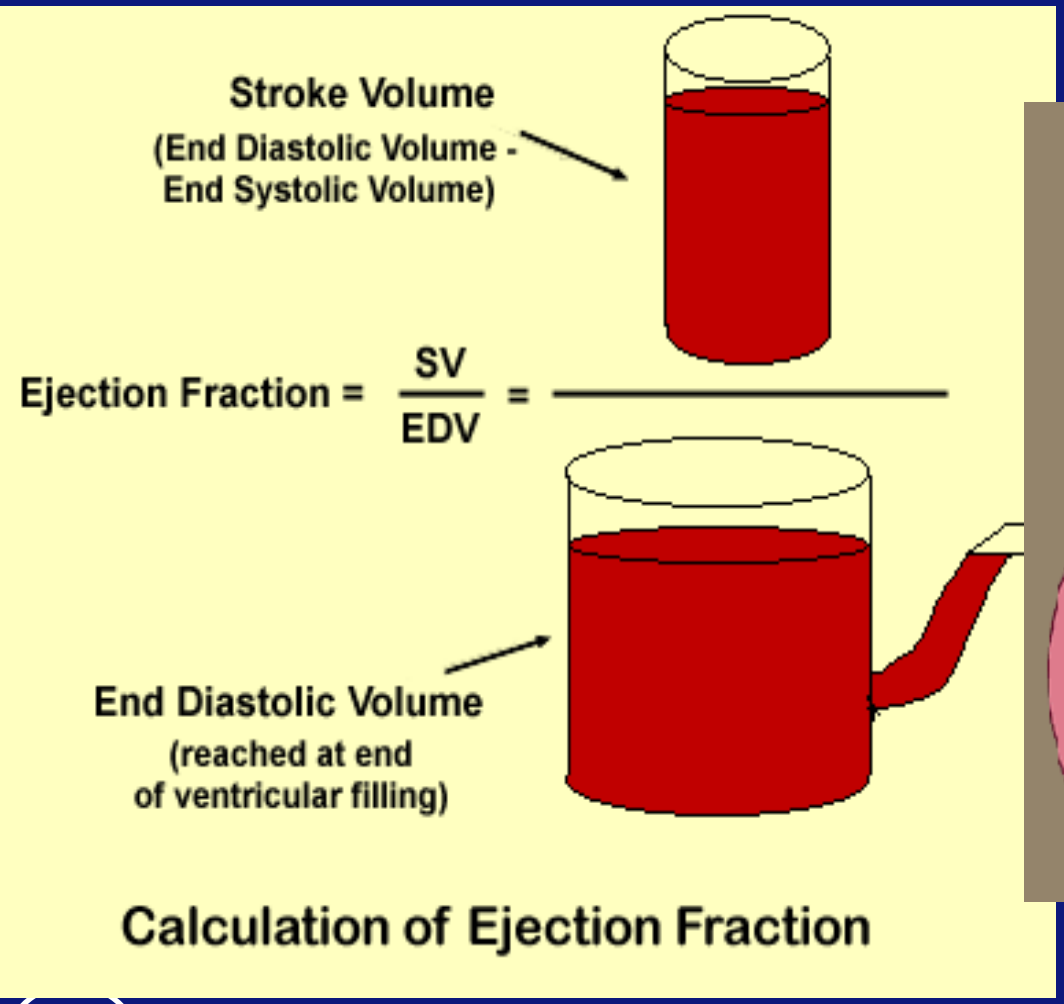
- Volume of blood in ventricles at end diastole
- Depends on venous return
- Depends on compliance

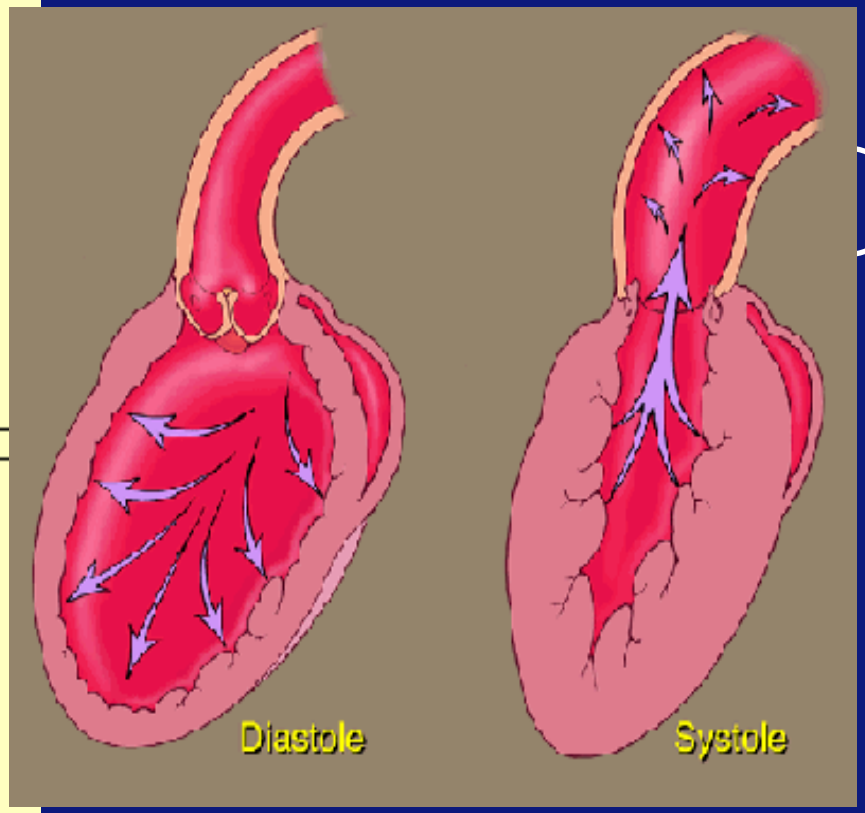
Afterload

- Force needed to eject blood into circulation
- Depends upon arterial BP, pulmonary artery pressure
- Valvular disease increases afterload

Ejection Fraction (EF)

- One of the measurements used by physicians to assess how well a patient's heart is functioning
- "Ejection" refers to the amount of blood that is pumped out of the heart's main pumping chamber during each heartbeat
- "Fraction" refers to the fact that, even in a healthy heart, some blood always remains within this chamber after each heartbeat
- An ejection fraction is a percentage of the blood within the chamber that is pumped out with every heartbeat
- Normal EF = 55 to 75 percent





90ml/140ml = 64% (EF 55-75% normal)

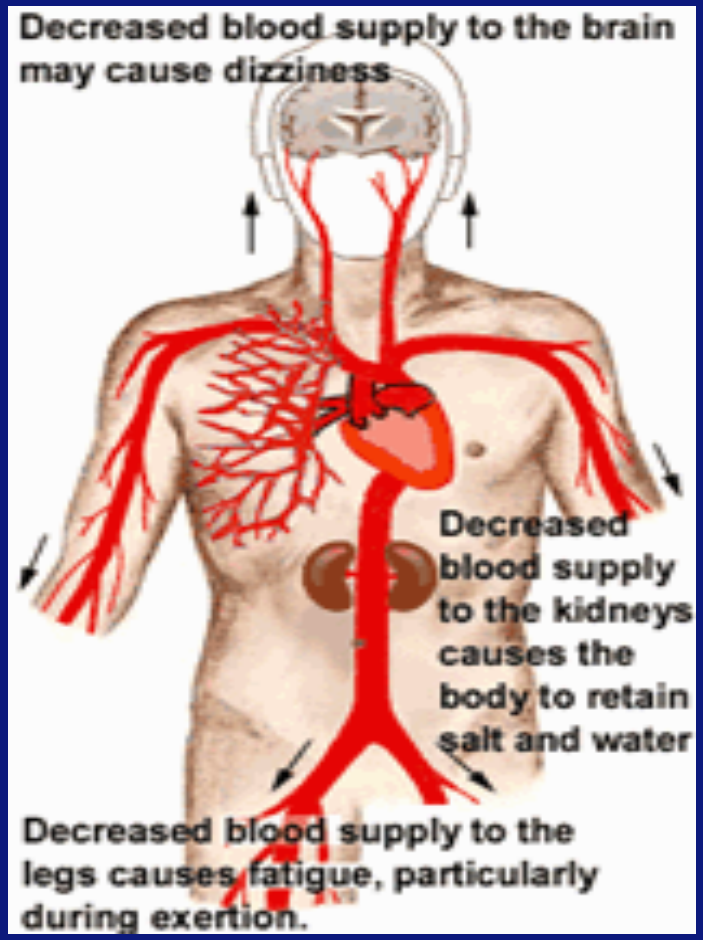
Keys To Understanding HF

- All organs (liver, lungs, legs, etc.) return blood to heart
- When heart begins to fail/ weaken → unable to pump blood forward→fluid backs up → Increase pressure within all organs
- Organ response
  - LUNGS: congested → increase effort to breathe →fluid starts to escape into alveoli (pulmonary edema) → fluid interferes with O2 exchange (hypoxia) → aggravates shortness of breath
  - Shortness of breath during exertion →may be early symptoms →progresses → later require extra pillows at night to breathe (orthopnea) and experience "P.N.D." or paroxysmal nocturnal dyspnea

Keys To Understanding HF

- LEGS, ANKLES, FEET: blood from feet and legs → back-up of fluid and pressure in these areas, as heart unable to pump blood as promptly as received → increase fluid within feet and legs (pedal/dependent edema) and increase in weight

Heart Failure



Heart Failure
Etiology

- *Systolic Failure* - *most common*
  - Hallmark finding: Decrease in ***left ventricular ejection fraction <40%*** (EF)
    - Due to
      - Impaired contractile function (e.g., MI)
      - Increased afterload (e.g., hypertension)
      - Cardiomyopathy
      - Mechanical abnormalities (e.g., valve disease)

Heart Failure
Etiology

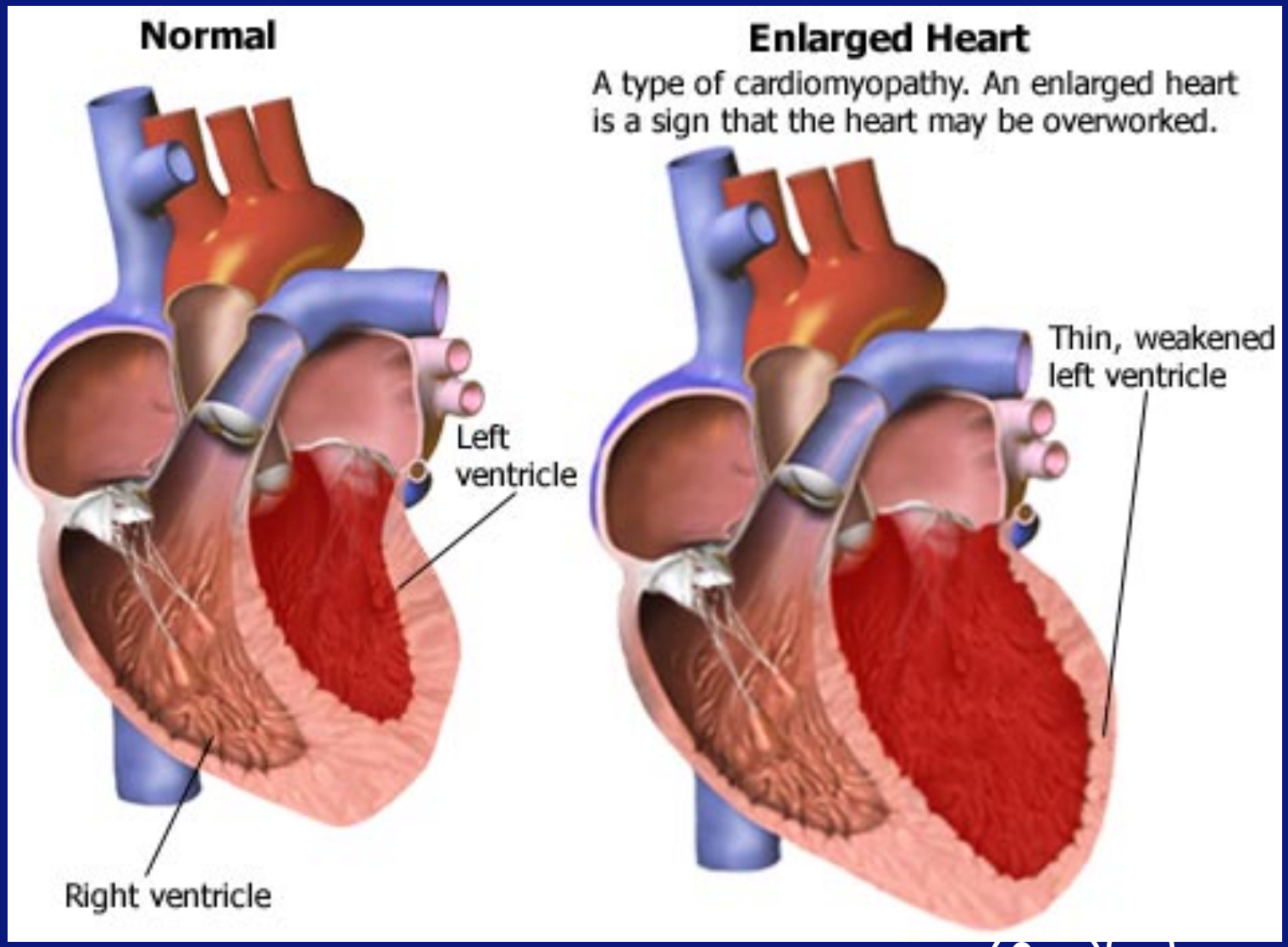
Diastolic failure

- Impaired ability of ventricles to relax and fill during diastole ➔ decrease stroke volume and CO
- Diagnosis based on presence of pulmonary congestion, pulmonary hypertension, ventricular hypertrophy
- **Normal ejection fraction (EF)-**

Heart Failure
Etiology

- *Mixed systolic and diastolic failure*
  - Seen in disease states such as dilated cardiomyopathy (DCM)
  - Poor EFs (<35%)
  - High pulmonary pressures

- *Biventricular failure*
  - Both ventricles may be dilated and have poor filling and emptying capacity


Normal
Left ventricle
Right ventricle
Enlarged Heart
A type of cardiomyopathy. An enlarged heart is a sign that the heart may be overworked.
Thin, weakened left ventricle

Heart Failure
Pathophysiology

A. Cardiac compensatory mechanisms

1. Tachycardia
2. Ventricular dilation - Frank Starling's law
3. Myocardial hypertrophy

Heart Failure
Pathophysiology

B. Homeostatic Compensatory Mechanisms

Activation of Sympathetic Nervous System (First line)

1. In vascular system resulting in vasoconstriction

2. Kidneys
   i. Decrease renal perfusion → Renin angiotensin release
   ii. Aldosterone release → Na and H_2O retention
3. Liver
   i. Stores venous volume causing ascites, hepatomegaly

Heart Failure

Pathophysiology

Counter Regulatory Response

- Increase Na → release of Anti diuretic hormone (ADH)
- Release of atrial natriuretic factor (ANP) and BNP → Na and H_20 excretion
  - Thus *Prevents* severe cardiac decompensation

Heart Failure

Pathophysiology

Counter Regulatory Response

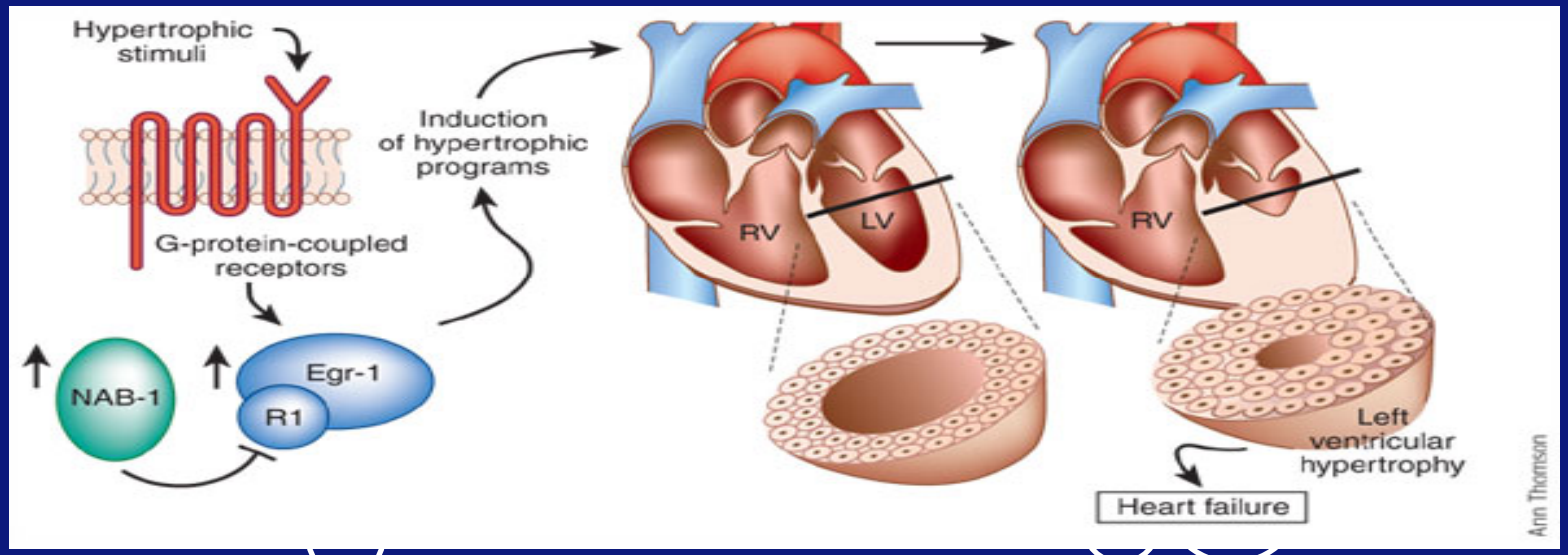
- *Neurohormonal responses:* *Endothelin* - stimulated by ADH, catecholamines, and angiotensin II
  - Arterial vasoconstriction
  - Increase in cardiac contractility
  - Hypertrophy

Heart Failure

Pathophysiology

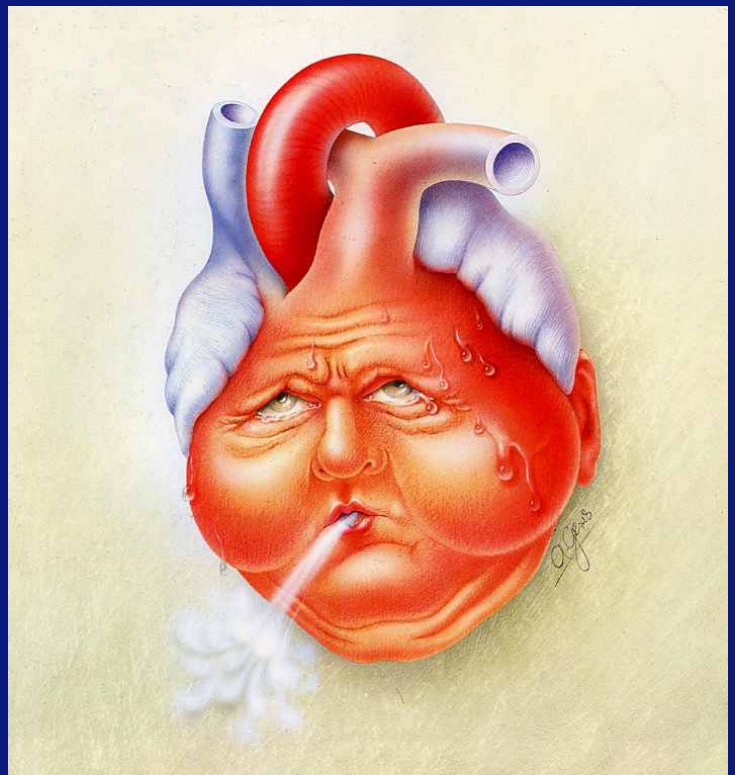
Counter Regulatory Response

- *Neurohormonal responses:* *Proinflammatory cytokines* (e.g., tumor necrosis factor)
  - Released by cardiac myocytes in response to cardiac injury
  - Depress cardiac function → *cardiac hypertrophy, contractile dysfunction, and myocyte cell death*



Heart Failure
Pathophysiology

- *Neurohormonal responses:* *Over time* → systemic inflammatory response → results
  - Cardiac wasting
  - Muscle myopathy
  - Fatigue



Heart Failure
Pathophysiology

Counter Regulatory Response

- Natriuretic peptides: atrial natriuretic peptide (ANP) and b-type natriuretic peptide (BNP)

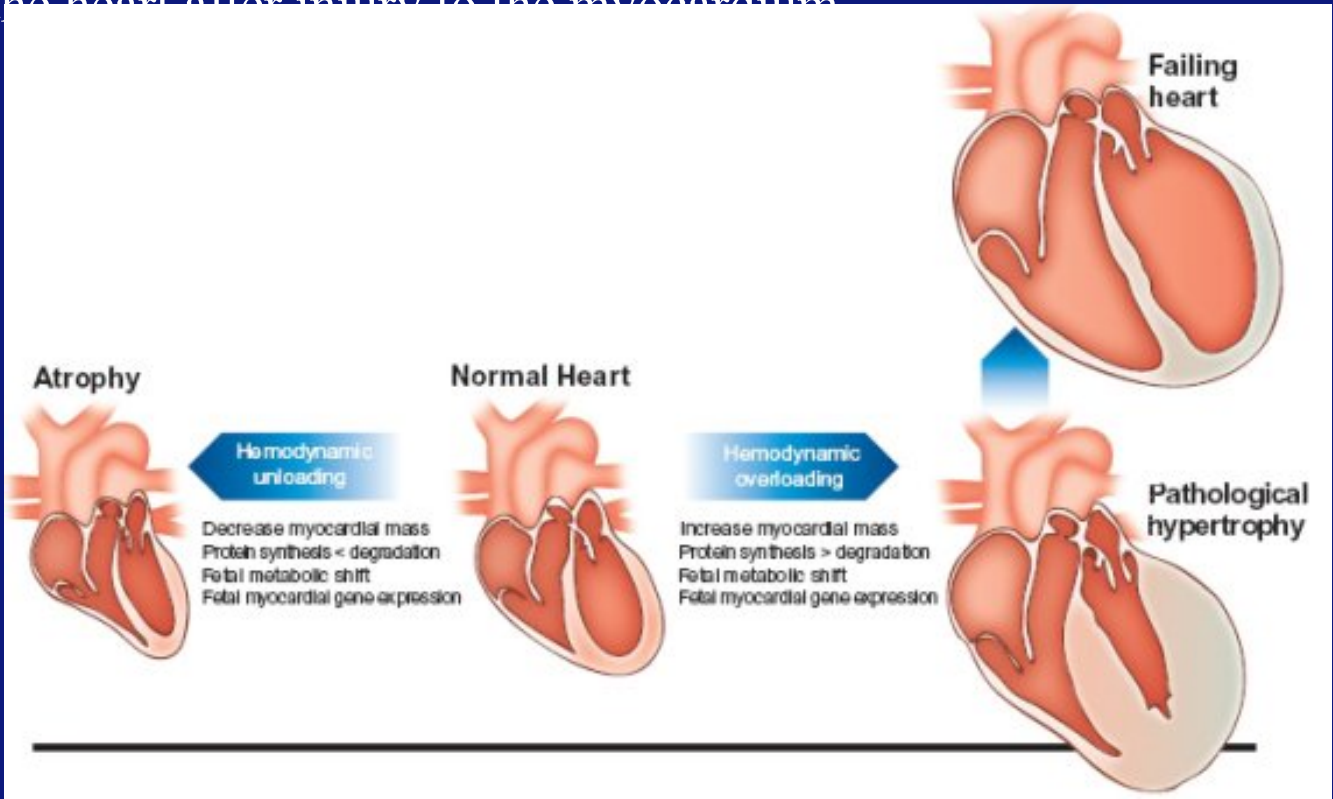
  - Released in response to increase in atrial volume and ventricular pressure
  - Promote venous and arterial vasodilation, *reduce preload and afterload*
  - Prolonged HF → *depletion of these factors*

Heart Failure
Pathophysiology

- *Consequences of compensatory mechanisms*
  - *Ventricular dilation:* Enlargement of heart chambers → elevated left ventricular pressure → initially effective adaptive mechanism → *then mechanism inadequate* → *cardiac output decrease*
  - *Frank-Starling law:* Initially increase venous return results in increase in force of contraction → later increase ventricular filling and myocardial stretch eventually results in *ineffective contraction*
  - *Hypertrophy:* Increase in muscle mass and cardiac wall thickness in response to chronic dilation → heart muscle poor contractility, increase in oxygen needs, poor coronary artery circulation, *prone to ventricular dysrhythmias (sudden cardiac death)*

Heart Failure
Pathophysiology

- *Ventricular remodeling/ cardiac remodeling*
  - Refers to the changes in size, shape, structure and physiology of the heart after injury to the myocardium



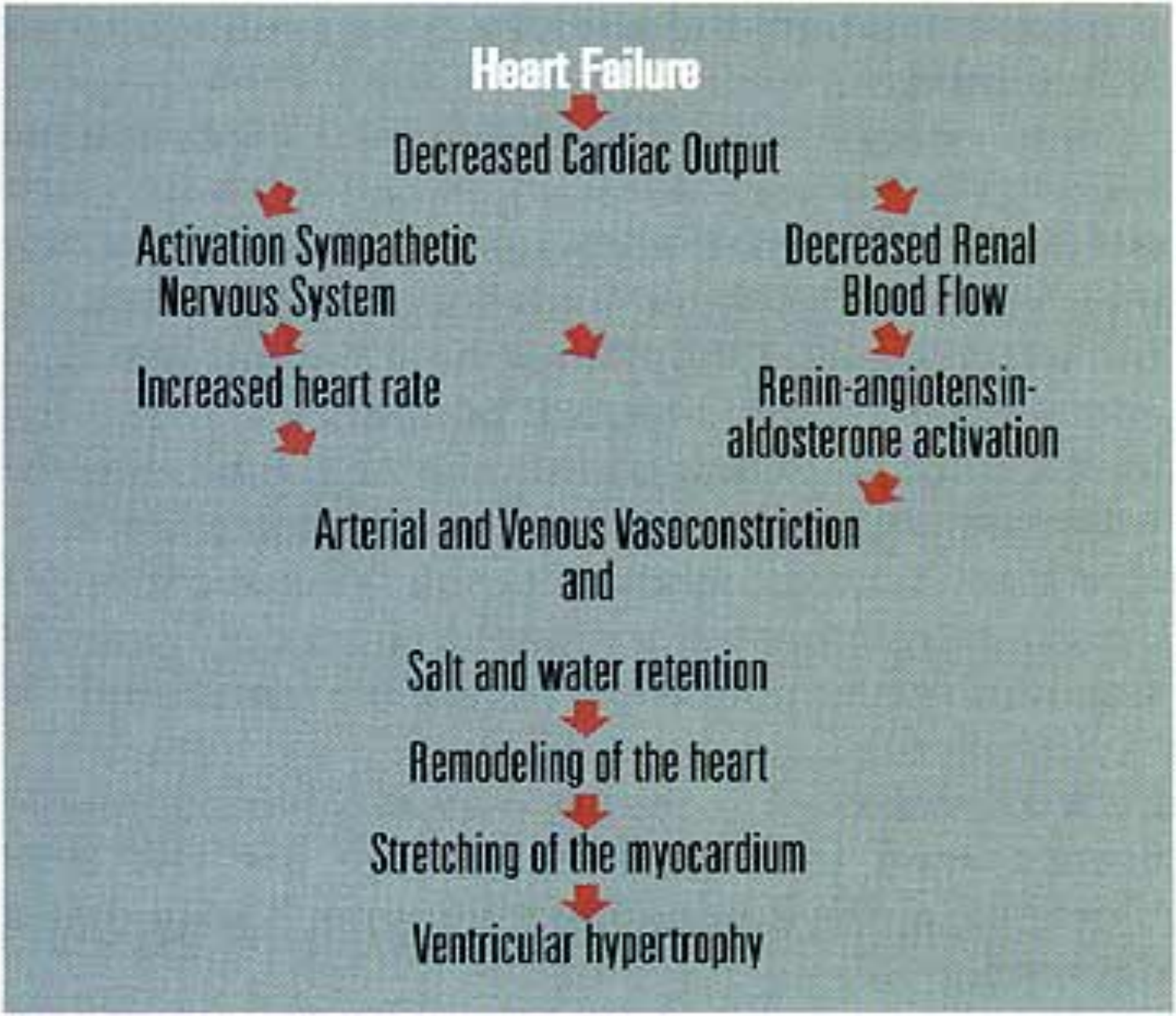
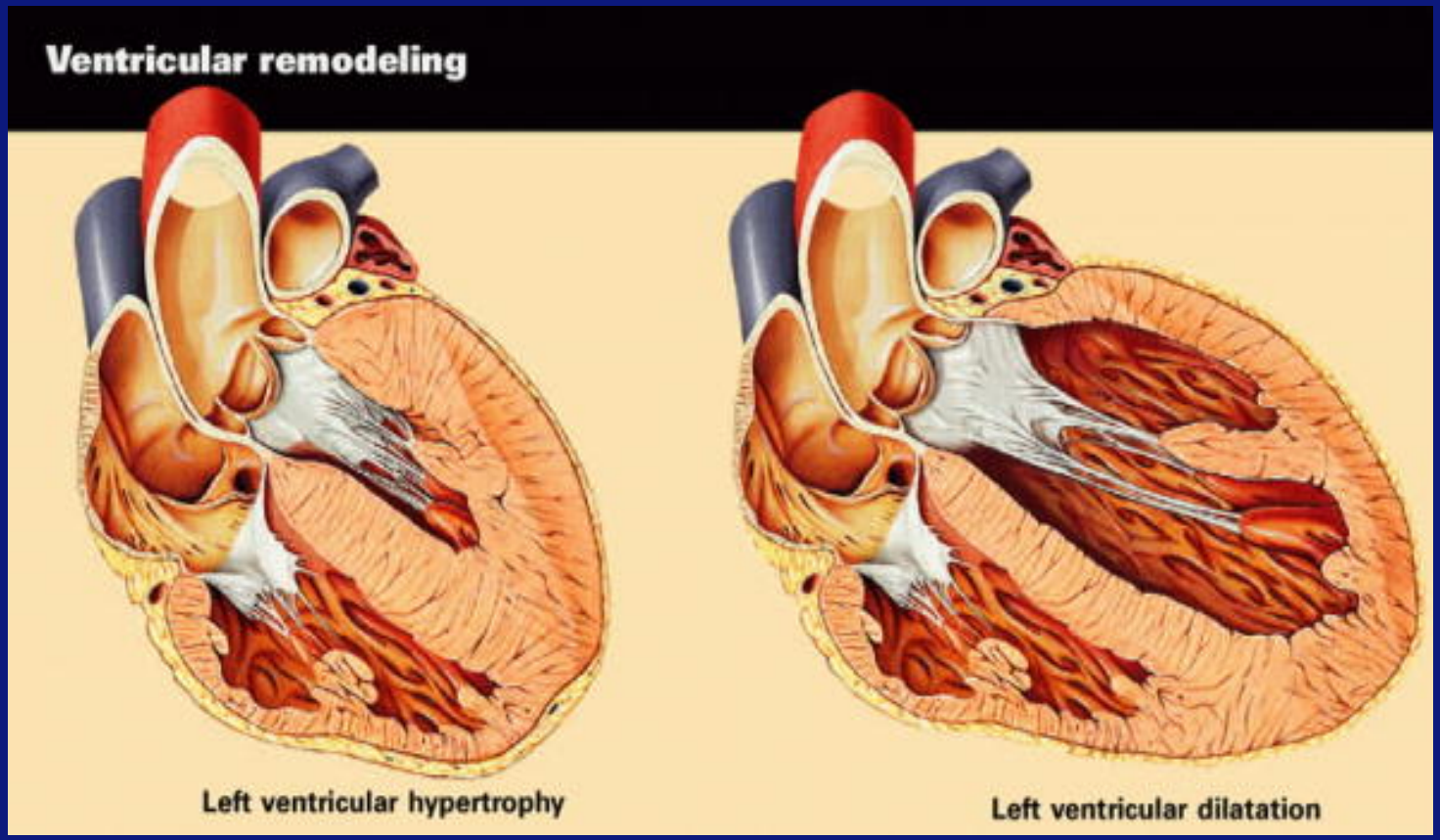


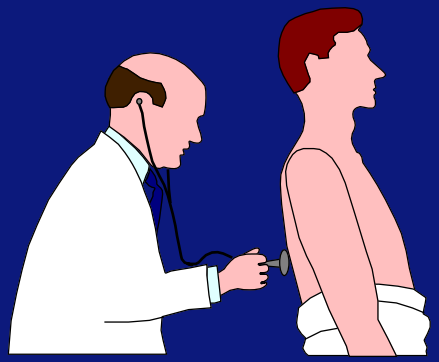
Figure 1. *Heart Failure Cycle.*

Ventricular Remodeling

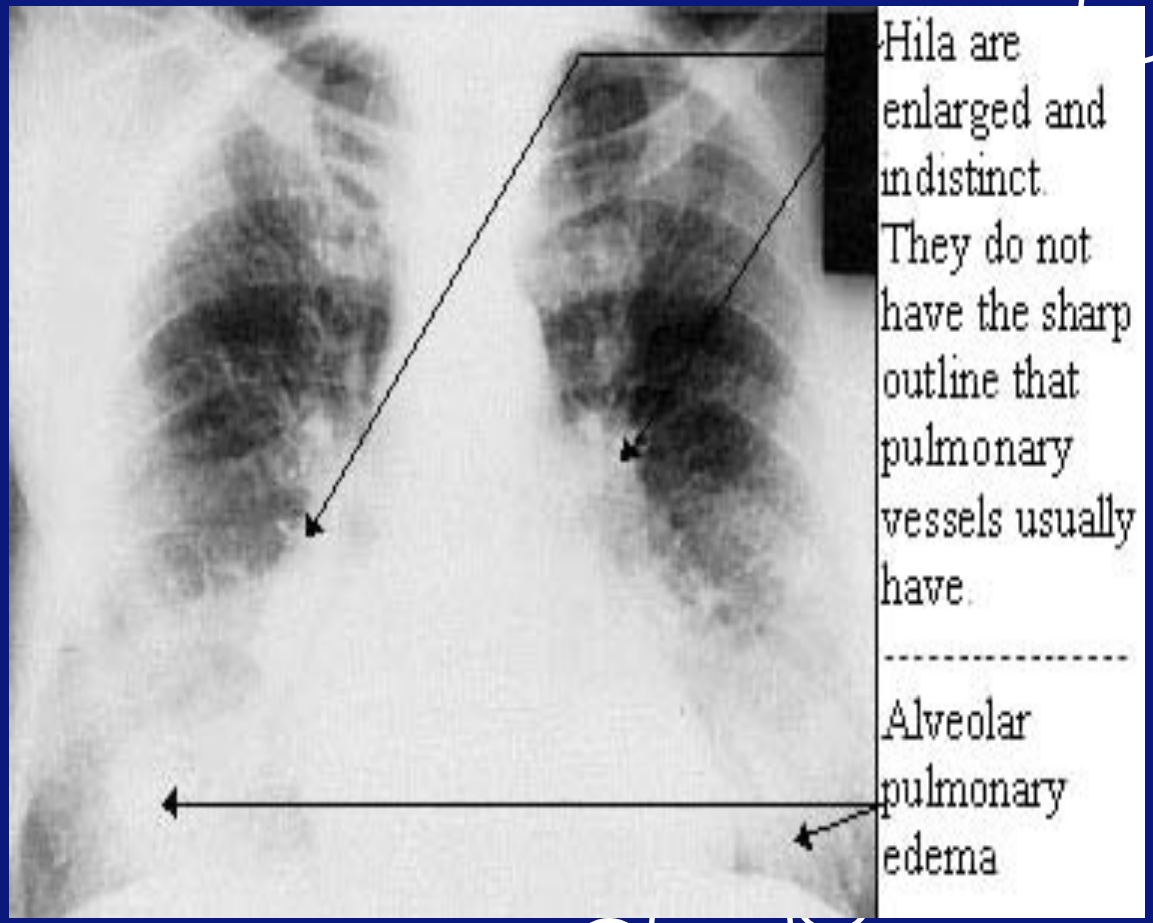


End Result

FLUID OVERLOAD ➔Acute Decompensated Heart Failure / Pulmonary Edema



Medical Emergency!!



Heart Failure
Classification Systems

- New York Heart Association (NYHA) Functional Classification of HF
  - Classes I to IV
- ACC/AHA Stages of HF (newer)
  - Stages A to D

Heart Failure
Classification Systems

New York Heart Association (NYHA) Classification of Heart Failure

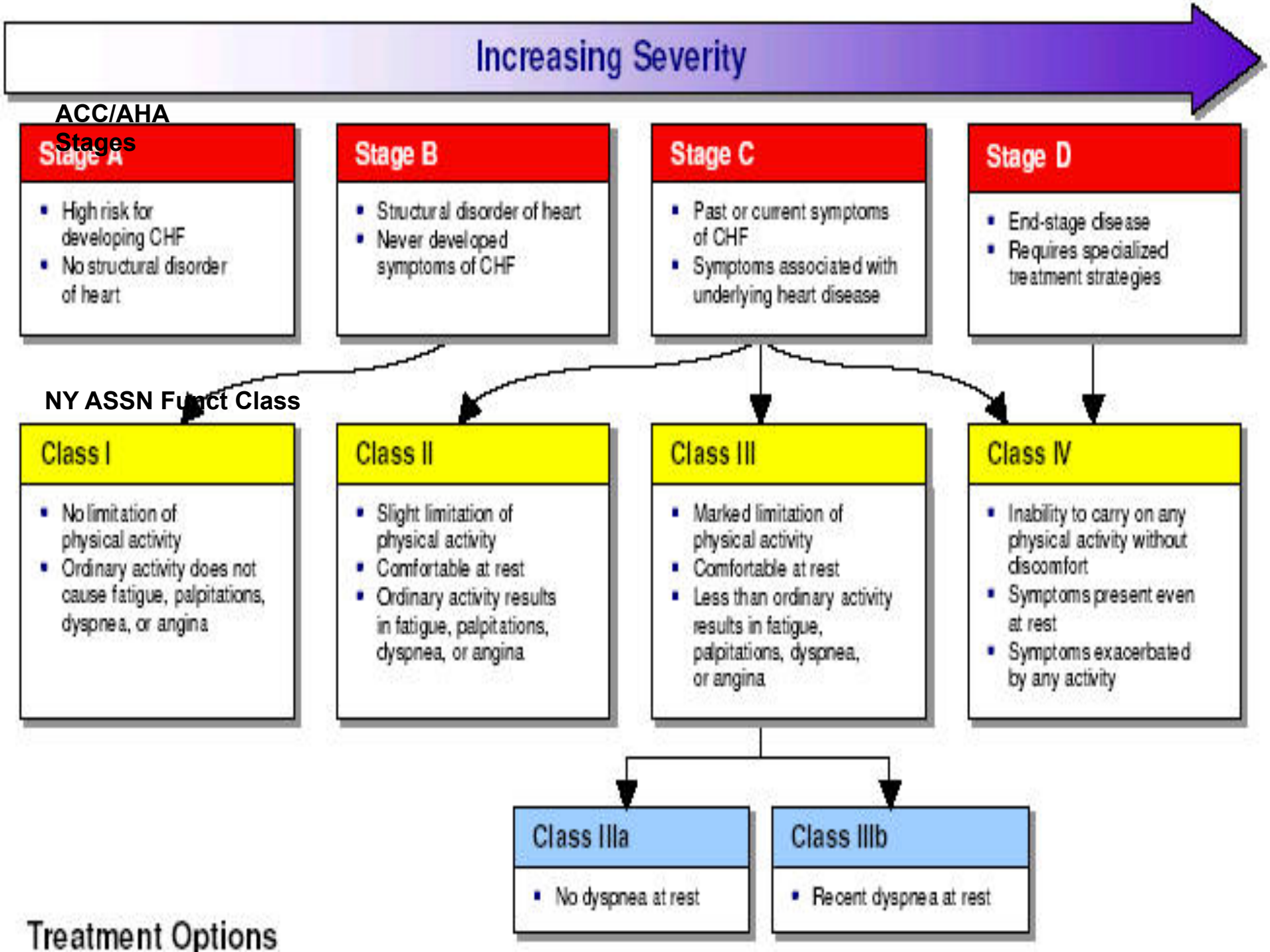
Class	Patient Symptoms
Class I (Mild)	No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, rapid/irregular heartbeat (palpitation) or shortness of breath (dyspnea).
Class II (Mild)	Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in fatigue, rapid/irregular heartbeat (palpitation) or shortness of breath (dyspnea).
Class III (Moderate)	Marked limitation of physical activity. Comfortable at rest, but less than ordinary activity causes fatigue, rapid/irregular heartbeat (palpitation) or shortness of breath (dyspnea).
Class IV (Severe)	Unable to carry out any physical activity without discomfort. Symptoms of fatigue, rapid/irregular heartbeat (palpitation) or shortness of breath (dyspnea) are present at rest. If any physical activity is undertaken, discomfort increases.

Heart Failure

Classification Systems

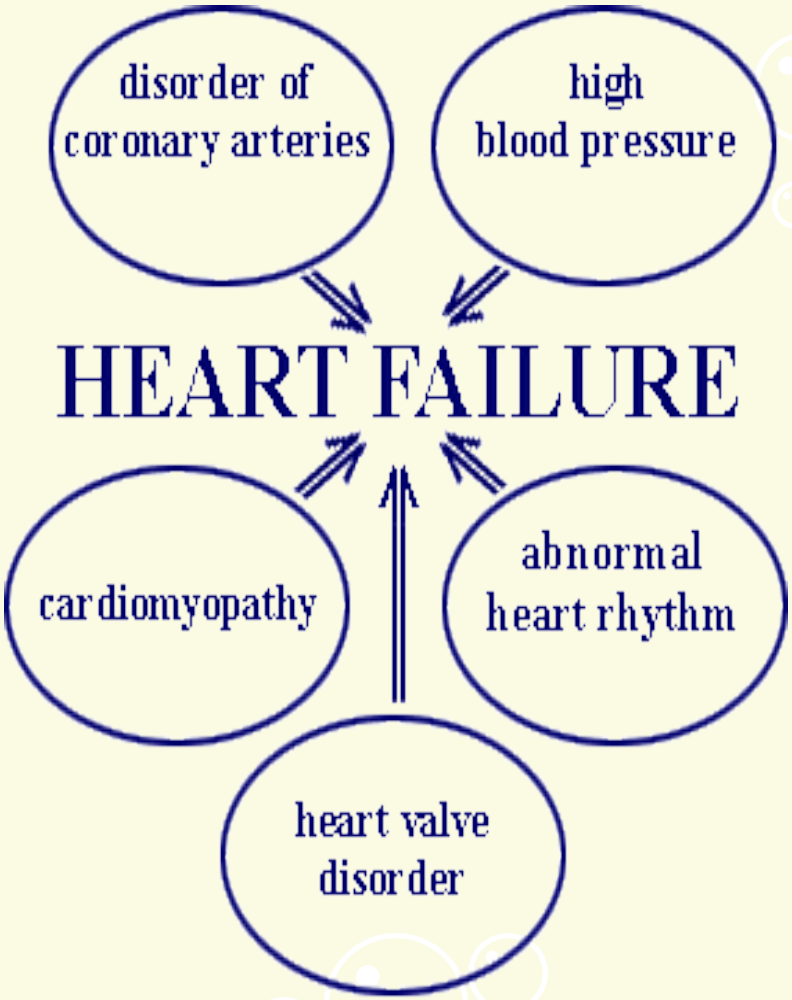
AHA/ACC Stage	Examples
Stage A Patients at high risk for heart failure but without structural heart disease or symptoms of heart failure	Hypertension, diabetes mellitus, obesity, CAD (post-MI or revascularization), peripheral vascular disease, CVA, family history, exposure to cardiac toxins
Stage B Patients with structural heart disease but without signs and symptoms of heart failure	Prior MI, left ventricular hypertrophy or reduced LVEF, asymptomatic valvular disease
Stage C Patients with structural heart disease with prior or current symptoms of heart failure	Known structural heart disease and dyspnea, fatigue, reduced exercise tolerance
Stage D Patients with refractory heart failure requiring specialized interventions	Marked symptoms at rest despite maximal medical therapy, with recurrent hospitalizations

AHA, American Heart Association; ACC, American College of Cardiology; NYHA, New York Heart Association; CAD, coronary artery
cerebrovascular accident; MI, myocardial infarction; LVEF, left ventricular ejection fraction.


Increasing Severity
ACC/AHA Stages
Stage A
High risk for developing CHF
No structural disorder of heart
Stage B
Structural disorder of heart
Never developed symptoms of CHF
Stage C
Past or current symptoms of CHF
Symptoms associated with underlying heart disease
Stage D
End-stage disease
Requires specialized treatment strategies
NY ASSN Funct Class
Class I
No limitation of physical activity
Ordinary activity does not cause fatigue, palpitations, dyspnea, or angina
Class II
Slight limitation of physical activity
Comfortable at rest
Ordinary activity results in fatigue, palpitations, dyspnea, or angina
Class III
Marked limitation of physical activity
Comfortable at rest
Less than ordinary activity results in fatigue, palpitations, dyspnea, or angina
Class IV
Inability to carry on any physical activity without discomfort
Symptoms present even at rest
Symptoms exacerbated by any activity
Class IIIa
No dyspnea at rest
Class IIIb
Recent dyspnea at rest
Treatment Options

Heart Failure
Risk Factors

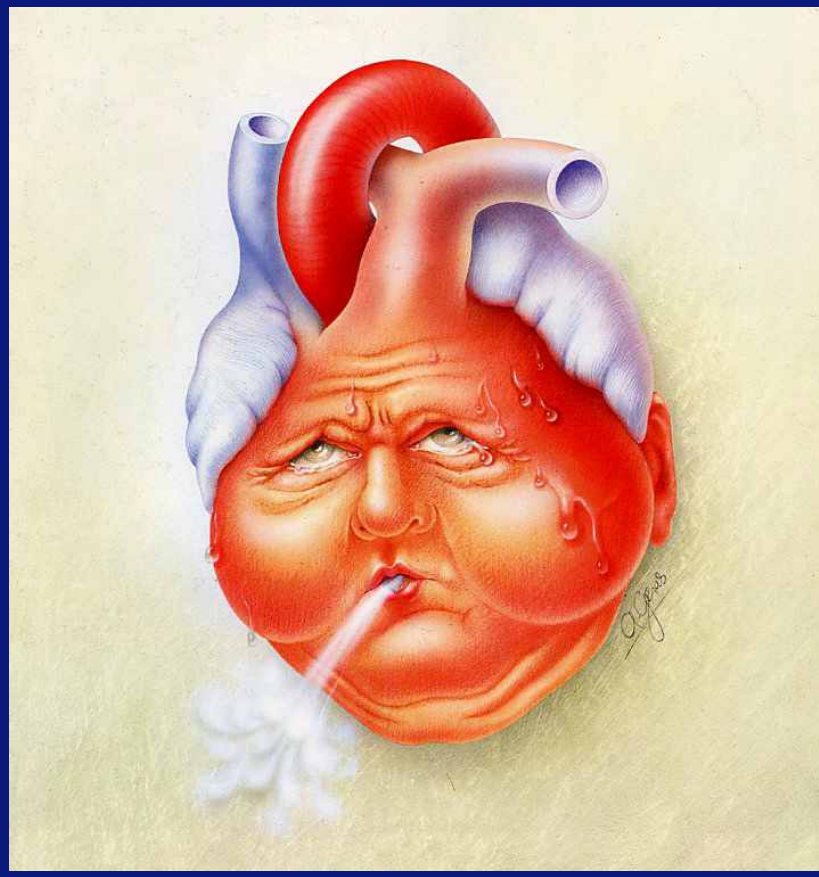
- ***Primary risk factors***
  - Coronary artery disease (CAD)
  - Advancing age
- ***Contributing risk factors***
  - Hypertension
  - Diabetes
  - Tobacco use
  - Obesity
  - High serum cholesterol
  - African American descent
  - Valvular heart disease
  - Hypervolemia



Heart Failure

Causes

1. *Impaired cardiac function*
   - Coronary heart disease
   - Cardiomyopathies
   - Rheumatic fever
   - Endocarditis
2. *Increased cardiac workload*
   - Hypertension
   - Valvular disorders
   - Anemias
   - Congenital heart defects
3. *Acute non-cardiac conditions*
   - Volume overload
   - Hyperthyroid, Fever,infection



Heart Failure
Causes

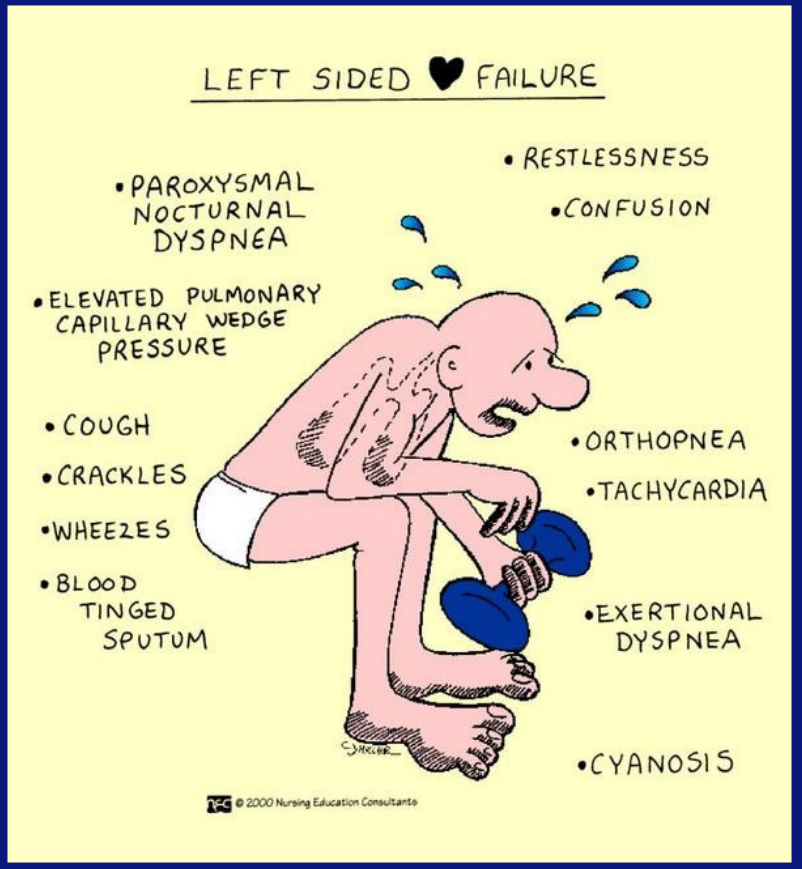
1. *Systolic versus Diastolic*
   - Systolic - loss of contractility get decease CO
   - Diastolic - decreased filling or preload
2. *Left sided versus Right sided*
   - Left ventricle - lungs
   - Right ventricle - peripheral
3. *High output vs Low output*
   - Hypermetabolic state
4. *Acute versus Chronic*
   - Acute MI
   - Chronic Cardiomyopathy

Symptoms


Shortness of breath
Swelling of feet & legs
Chronic lack of energy
Difficulty sleeping at night due to breathing problems
Swollen or tender abdomen with loss of appetite
Cough with frothy Sputum
Increased urination at night
Confusion and/or impaired memory

Heart Failure
Symptoms

- Signs and symptoms
  - Dyspnea
  - Orthopnea & PND ??
  - Cheyne Stokes
  - Fatigue
  - Anxiety
  - Rales



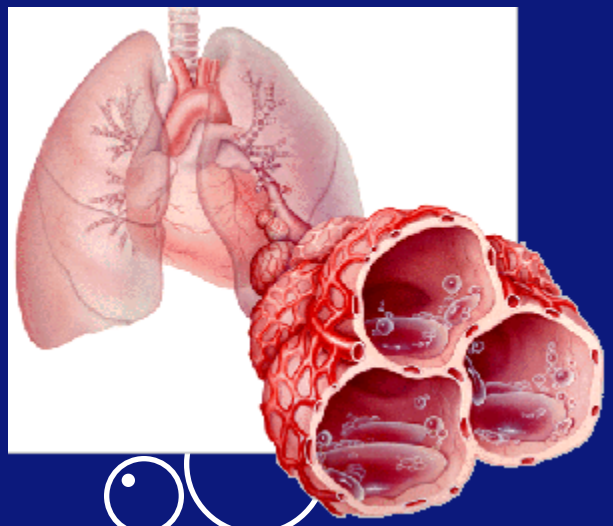
- Orthopnea: dyspnea on lying flat - due to increased distribution of blood to the pulmonary circulation while recumbent

Paroxysmal Nocturnal Dyspnoea

- Attacks of severe shortness of breath and coughing that generally occur at night
- It usually awakens the person from sleep, and may be quite frightening
- *Cause:*
  - Caused in part by the depression of the respiratory center during sleep, which may reduce arterial oxygen tension, particularly in patients with reduced pulmonary compliance
  - Also, in the horizontal position there is redistribution of blood volume from the lower extremities and splanchnic beds to the lungs
- Little effect in normal individuals, but in patients with failing left ventricle, there is a significant reduction in vital capacity and pulmonary compliance with resultant shortness of breath

Heart Failure
Clinical Manifestations

- Acute decompensated heart failure (ADHF) ➔ *Pulmonary edema*, often life-threatening
  - Early
    - Increase in the respiratory rate
    - Decrease in PaO_2 (hypoxia)
  - Later
    - Tachypnea
    - Respiratory acidosis



Acute Decompensated Heart Failure (ADHF)

Clinical Manifestations

Physical findings

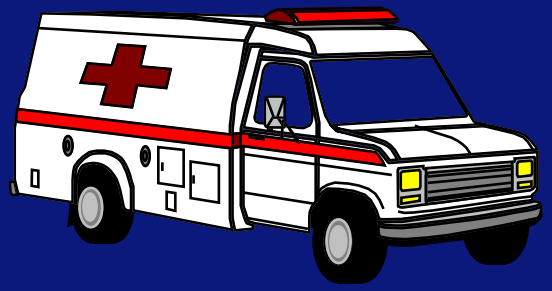
- Orthopnea
- Dyspnea, Tachypnea
- Use of accessory muscles of respiration
- Cyanosis
- Cool and clammy skin
- S3 gallop rhythm

Physical findings

- Cough with frothy, blood-tinged sputum
- Breath sounds: Crackles, wheezes, rhonchi
- Tachycardia
- Hypotension or hypertension

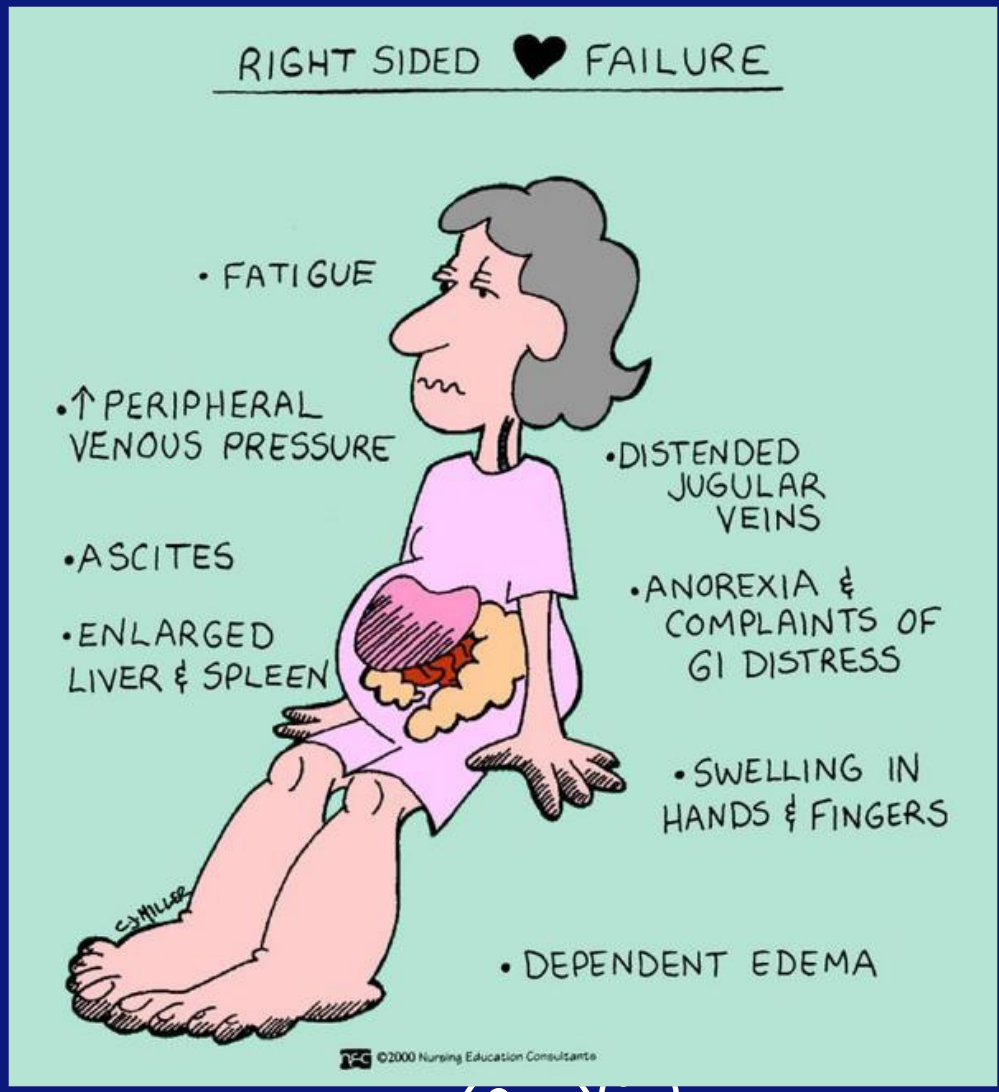
Person Literally Drowning In Secretions

Immediate Action Needed



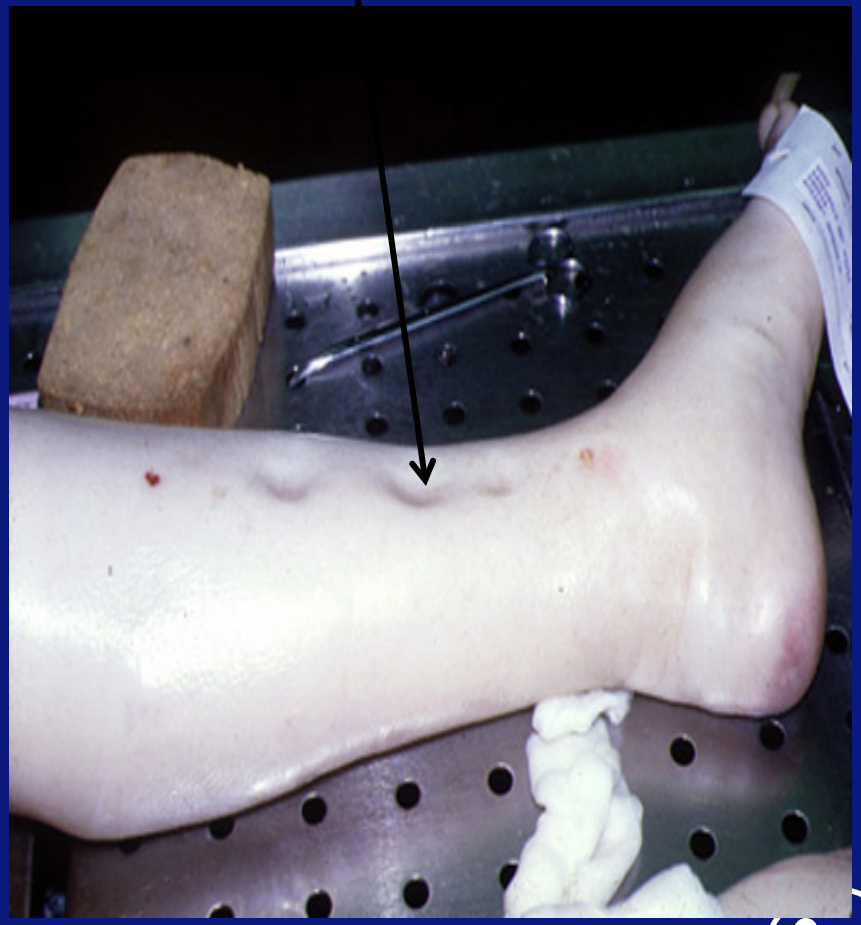
Right Heart Failure

- *Signs and Symptoms*
  - Fatigue, weakness, lethargy
  - weight gain
  - Increase abdominal girth
  - Anorexia
  - Right upper quadrant pain
  - elevated neck veins
  - Hepatomegaly
  - May not see signs of LVF



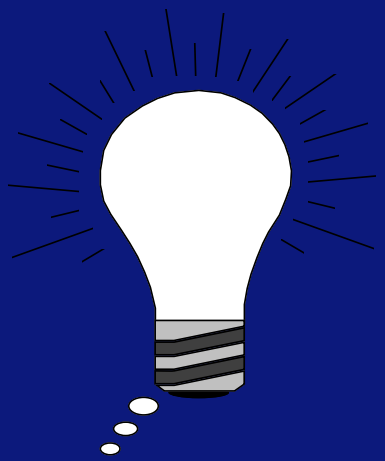
What does this show?

What is present in this extremity, common to right sided HF?



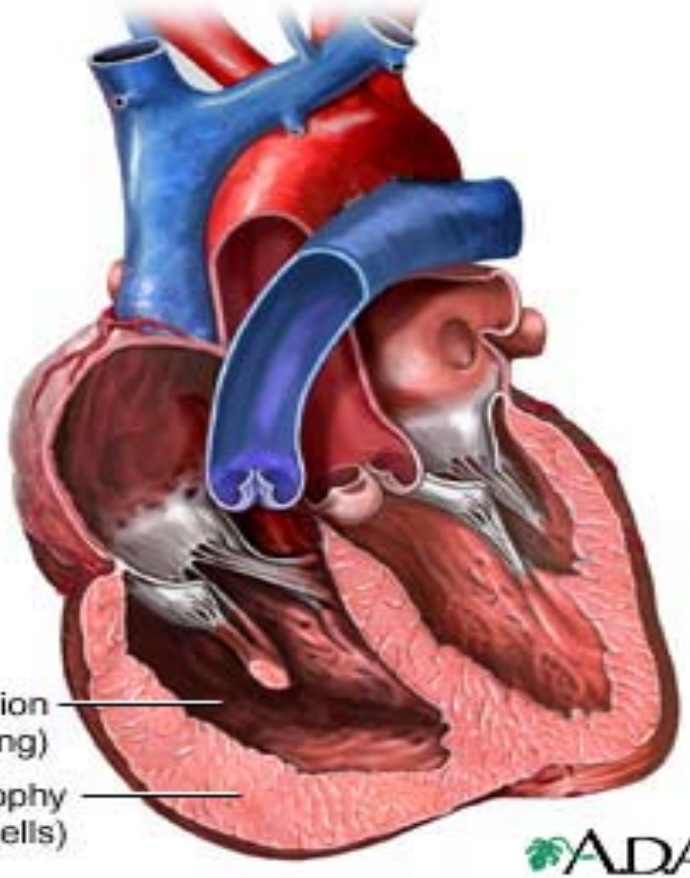
Can You Have RVF Without LVF?

- What is this called?



COR PULMONALE

Cor pulmonale, or right-sided heart failure, is an enlargement of the right ventricle due to high blood pressure in the lungs usually caused by chronic lung disease



Heart Failure
Complications

- Pleural effusion
- Atrial fibrillation (most common dysrhythmia)
  - Loss of atrial contraction (kick) – necessary for 20-25% of cardiac output
    - Reduce CO by 20% to 25%
  - Promotes thrombus/embolus formation
    - Increase risk for stroke

Heart Failure
Complications

- High risk of *fatal dysrhythmias* (e.g., sudden cardiac death, ventricular tachycardia) with HF and an EF <35%

- HF lead to severe hepatomegaly, especially with RV failure
  - Fibrosis and cirrhosis (cardiac cirrhosis) - develop over time
- Renal insufficiency or failure (*cardiorenal syndrome*)

Heart Failure
Initial Evaluation

Primary goal - Determine underlying cause

- Thorough history and physical examination – to identify cardiac and noncardiac disorders or behaviors that might cause or accelerate the development or progression of HF

- Volume status and vital signs should be assessed

Heart Failure

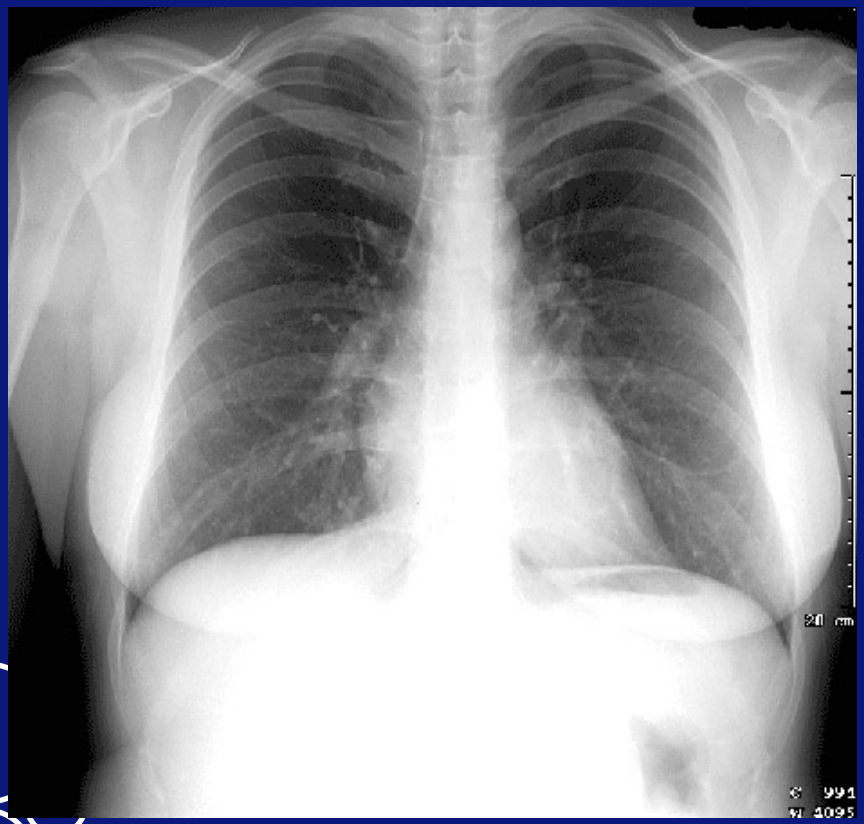
Diagnostic Tests

Initial Lab workup includes

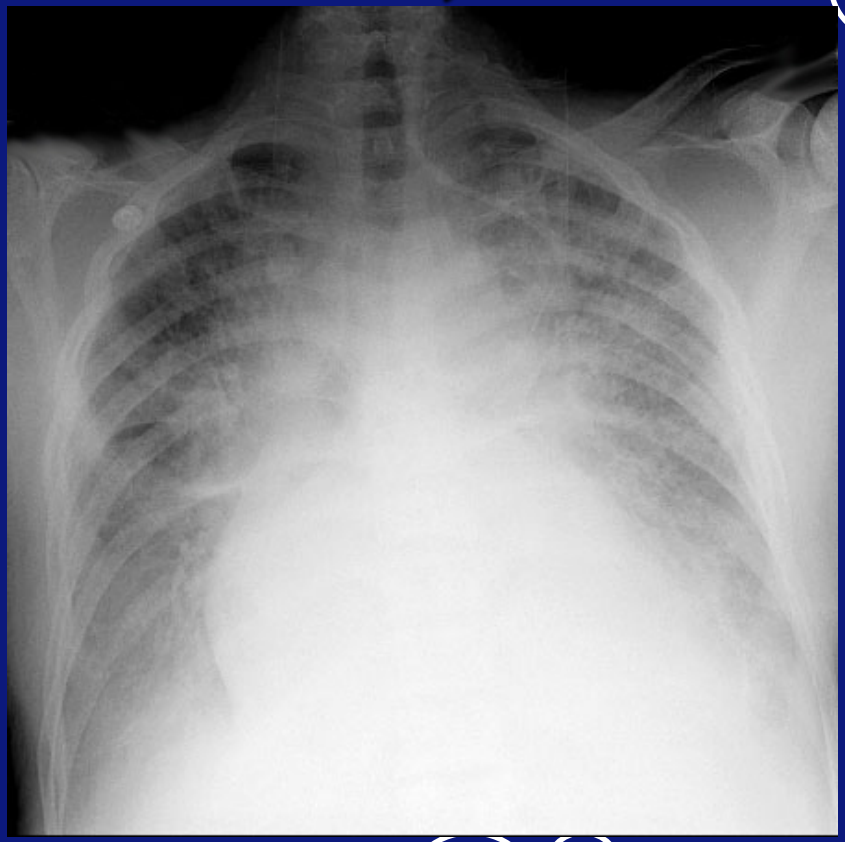
1. ECG
2. Chest X ray
3. Complete blood count (CBC)
4. Urinalysis
5. Serum electrolytes (including calcium and magnesium)
6. Blood urea nitrogen (BUN) and serum creatinine (Cr)
7. Glucose
8. Fasting lipid profile (FLP)
9. liver function tests (LFT)
10. Thyroid-stimulating hormone (TSH)
11. Cardiac Troponins
12. Beta naturetic peptide (BNP)
13. Arterial Blood gas (ABG)

Chest xray

Normal



Pulmonary edema



Heart Failure
Diagnostic Tests

- (2-D or 3-D echo) with Doppler should be performed during initial evaluation of patients presenting with HF to assess ventricular function, size, wall thickness, wall motion, and valve function

Echocardiography

- EF is the "single most important measurement in HF"
- It helps define etiology and type of HF

But →

- There is no correlation between symptoms and EF

Heart Failure
Diagnostic Studies

- *Invasive hemodynamic monitoring*
  - Can be useful for carefully selected patients with acute HF who have persistent symptoms despite empiric adjustment of standard therapies and
  a. Whose fluid status, perfusion, or systemic or pulmonary vascular resistance is uncertain
  b. Whose systolic pressure remains low, or is associated with symptoms, despite initial therapy
  c. Whose renal function is worsening with therapy
  d. Who require parenteral vasoactive agents
- *Coronary angiography* if ischemia is likely cause of heart failure.

Heart Failure

Emergency Management

U	Upright Position
N	Nitrates
L	IV diuresis
O	Oxygen
A	ACE, ARBs, Aldactone, Amiodarone
D	Digoxin, Dobutamine, Dopamine
M	Morphine Sulfate
E	Extremities Down

Common Factors That Precipitate Acute Decompensated HF

- Nonadherence with medication regimen, sodium and/or fluid restriction
- Acute myocardial ischemia
- Uncorrected high blood pressure
- AF and other arrhythmias
- Recent addition of negative inotropic drugs (e.g., verapamil, nifedipine, diltiazem, beta blockers)
- Pulmonary embolus
- Initiation of drugs that increase salt retention (e.g., steroids, thiazolidinediones, NSAIDs)
- Excessive alcohol or illicit drug use
- Endocrine abnormalities (e.g., diabetes mellitus, hyperthyroidism, hypothyroidism)
- Concurrent infections (e.g., pneumonia, viral illnesses)
- Additional acute cardiovascular disorders (e.g., valve disease endocarditis, myopericarditis, aortic dissection)

Heart Failure

Stage A

At Risk Of Developing Heart Failure but no structural heart disease yet:

- Adequate BP control
- Adequate Diabetes control
- Weight reduction
- Quit smoking
- Avoid cardiotoxins
- Lipid management
- Atrial fibrillation management

Heart Failure

Stage B

Structural Heart Disease Without Overt Symptoms

- Care measures as in Stage A along with:
  - Should be on ACE-I
  - Add beta blockers
  - Spironolactone – if LVEF <40%
- Surgical consultation for coronary artery revascularization and valve repair/replacement (as appropriate)

Heart Failure
Stage C

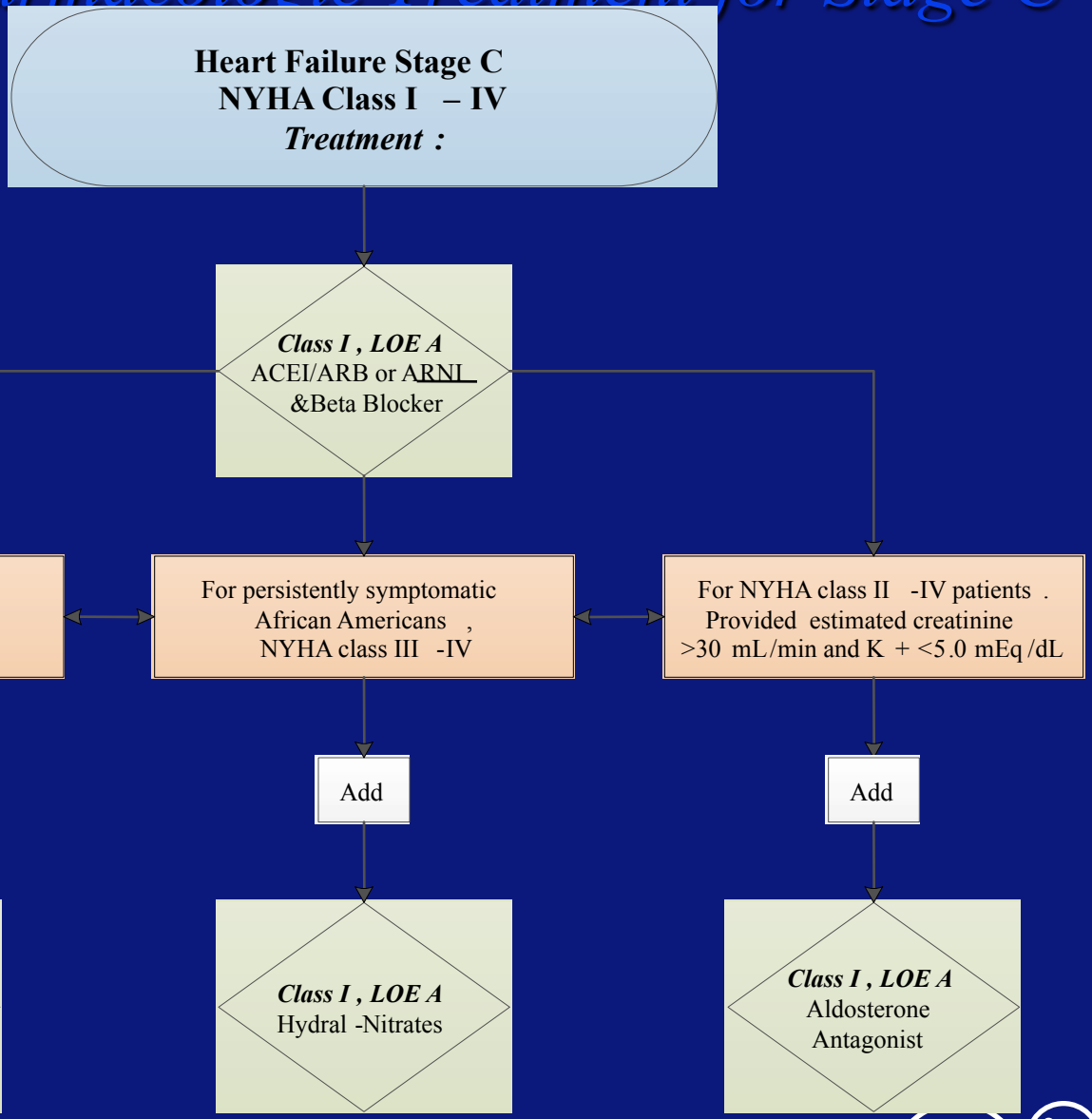
Structural Heart Disease With Overt Symptoms

Nonpharmacological Interventions

- ***Therapeutic life style changes:*** *Diet* → low salt, low fat, rich in fruit and veggie, increase fiber, water intake limited to 1.5 liters
- ***Smoking cessation***
- ***Activity & exercise***
- ***Duration of activity:*** Exercise training and rehab at least 30 min aerobic exercise/brisk walking with 5 days and ideally 7 days a week
  - ***Benefits:*** improve HRQOL, increase in functional status, improve exercise capacity and reduce hospitalization and mortality, improve endothelial function and improve O2 extraction from peripheral tissue

HRQOL – Health related quality of life

Pharmacologic Treatment for Stage C



Ivabradine

- In class II-III systolic heart failure patients on GDEM receiving BB at max tolerated dose with underlying NSR >70bpm at rest EF <35%

Heart Failure

Stage C

Device Therapy

- *Implantable Cardioverter Defibrillator (ICD)*
  - Nonischemic or ischemic heart disease (at least 40 days post-MI) with LVEF of ≤35% with NYHA class II or III symptoms or NYHA 1 with EF ≤30% on chronic medical therapy, who have reasonable expectation of meaningful survival for more than 1 year
- *Cardiac Resynchronization Therapy (CRT)*
  - Indicated for patients who have LVEF of 35% or less, sinus rhythm left bundle-branch block (LBBB) with a QRS duration of 150 ms or greater, and NYHA class II, III, or ambulatory IV symptoms on GDMT. Can be used in afib on or QRS 120-149 ms

Heart Failure

Stage D

Clinical Events and Findings Useful for Identifying Patients With Advanced HF

1. Repeated (≥2) hospitalizations or ED visits for HF in the past year
2. Progressive deterioration in renal function (e.g., rise in BUN and creatinine)
3. Weight loss without other cause (e.g., cardiac cachexia)
4. Intolerance to ACE inhibitors due to hypotension and/or worsening renal function
5. Intolerance to beta blockers due to worsening HF or hypotension
6. Frequent systolic blood pressure <90 mm Hg
7. Persistent dyspnea with dressing or bathing requiring rest
8. Inability to walk 1 block on the level ground due to dyspnea or fatigue
9. Recent need to escalate diuretics to maintain volume status, often reaching daily furosemide equivalent dose >160 mg/d and/or use of supplemental metolazone therapy
10. Progressive decline in serum sodium, usually to <133 mEq/L
11. Frequent ICD shocks

Heart Failure

Stage D

- All the measures of Stage A, B & C
- Until definitive therapy [e.g., coronary revascularization, Mechanical circulatory support, heart transplantation or resolution of the acute precipitating problem], patients with cardiogenic shock should receive temporary intravenous inotropic support to maintain systemic perfusion and preserve end-organ performance.

Heart Failure

Stage D

Mechanical Circulatory Support

- *Intraaortic balloon pump* (IABP) therapy
  - Used for cardiogenic shock
  - Allows heart to rest
- *Ventricular assist devices* (VADs)
  - Takes over pumping for the ventricles
  - Used as a bridge to transplant
- *Destination therapy-permanent*, implantable VAD
- *Cardiomyoplasty*- wrap latissimus dorsi around heart
- *Ventricular reduction* -ventricular wall resected
- *Transplant/Artificial Heart*

Heart Failure

Prognostic Factors

SBP	Admission and early post-discharge SBP inversely correlates with post-discharge mortality
Coronary artery disease (CAD)	Extent and severity of CAD appears to be a predictor of poor prognosis
Troponin release	Results in a 3-fold increase in in-hospital mortality and rehospitalization rate, a 2-fold increase in post-discharge mortality
Ventricular dyssynchrony	Increase in QRS duration occurs in approximately 40% of patients with reduced systolic function and is a strong predictor of early and late post-discharge mortality and rehospitalization
Renal impairment	Worsening renal function during hospitalization or soon after discharge is associated with an increase in in-hospital and post-discharge mortality

Heart Failure

Prognostic Factors

Hyponatremia	Defined as serum sodium < 135 mmol/l, occurs in approximately 25% of patients, and is associated with a 2- to 3-fold increase in post-discharge mortality
Clinical congestion at time of discharge	An important predictor of post-discharge mortality and morbidity
EF	Similar early post-discharge event rates and mortality between reduced and preserved EF
BNP/NT-proBNP	Elevated natriuretic peptides associated with increased resource utilization and mortality
Functional capacity at time of discharge	Pre-discharge functional capacity, defined by the 6-min walk test, is emerging as an important predictor of post-discharge outcomes

Take Home Message

- Heart failure is common problem in elderly and having prognosis worse then Carcinoma Lung
- It is clinical diagnosis supplemented by lab test and echo
- Echo can suggest the etiology of heart failure
- Diuretics are for acute relief and also for chronic management of fluid overload
- Look for the precipitating event for acute decompensation
- ARNI, ACE inhibitors/ARB, Beta blockers, Spironolactone improve prognosis in patient with reduced ejection fraction.
- Device therapy, when indicated improve prognosis, and survival.

Take Home Message

- Maintain patient on 2g sodium diet. Follow daily weight and determine target/ideal weight, which is not the dry weight - In order to prevent worsening azotemia and adjust the dose of diuretic accordingly
- Use Digoxin in most symptomatic heart failure, Digoxin level 0.5-0.9
- Encourage exercise training
- Consider a cardiology consultation in patients who fail to improve
- Heart transplantation is for end stage heart failure


WHO
WHAT
WHERE
WHEN
WHY
HOW
QUESTIONS
ANSWERS