25 September 2017

Pathophysiology of Cardiogenic Shock & Heart Failure

เอกราช อริยะชัยพาณิชย์

Heart Failure and Transplant Cardiology

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Presentation at

Chulalongkorn HEART FAILURE & TRANSPLANT CARDIOLOGY

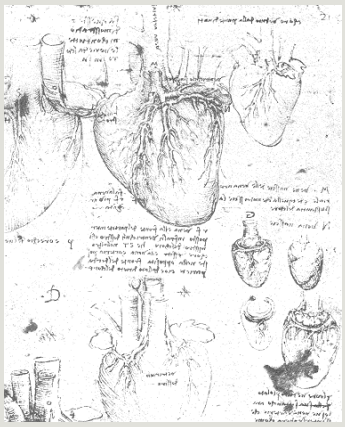
Agenda

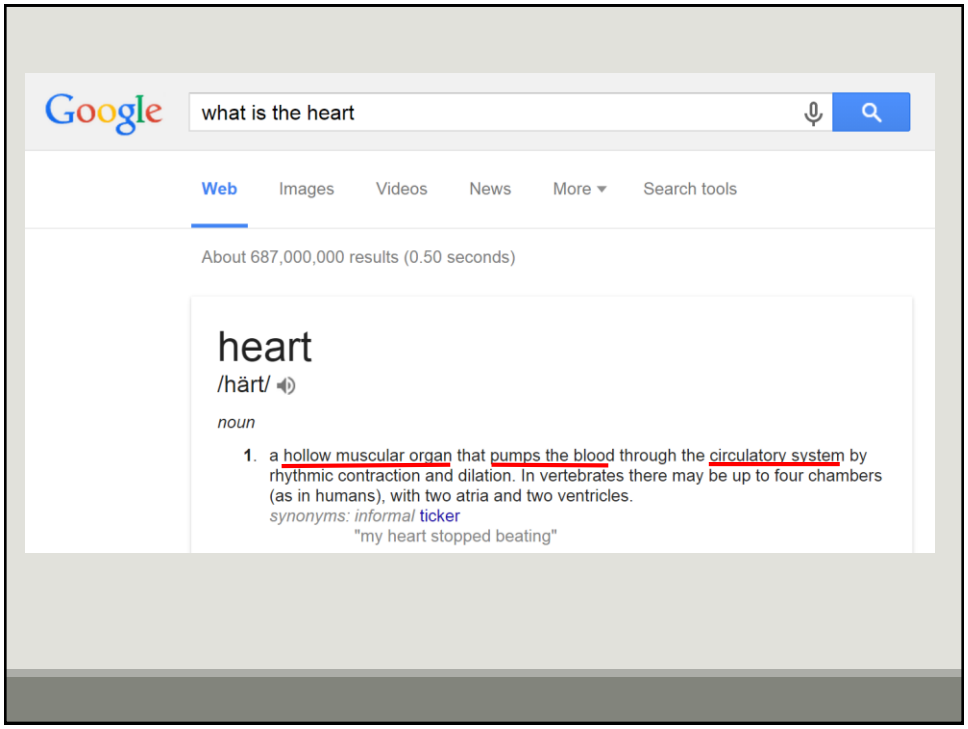
- Physiology of the heart
- Pathophysiology of shock
- Pathophysiology of heart failure

Chulalongkorn HEART FAILURE & TRANSPLANT CARDIOLOGY

http://fullpulse.weebly.com/conversation

1. What is the heart ?
2. What is the function of the heart ?





To pump the blood

Cardiac output (CO)

- The amount of blood that the heart pump in 1 minute (L/min)
- Normal = 6 L/min

Heart rate (bpm)

Stroke volume (ml/beat)

What regulate stroke volume

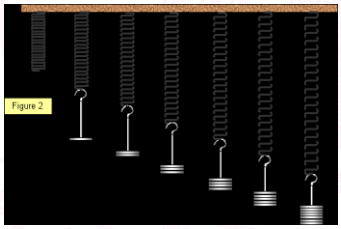
What regulate stroke volume

Preload

Afterload

Contractility

What is the preload ?

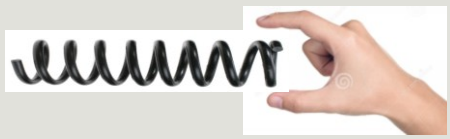


Chulalongkorn HEART FAILURE & TRANSPLANT CARDIOLOGY

Preload

1

2



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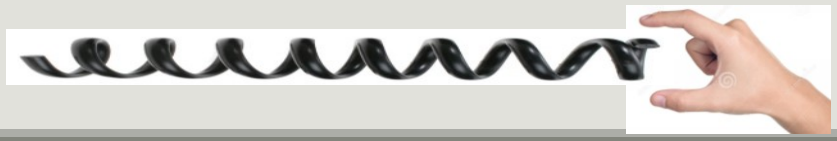
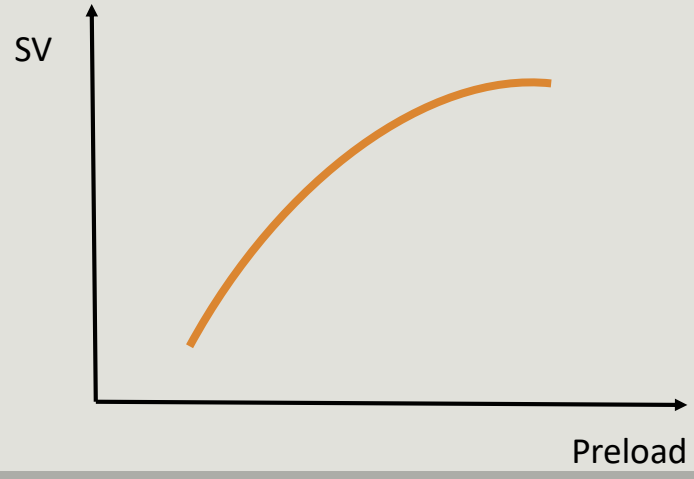


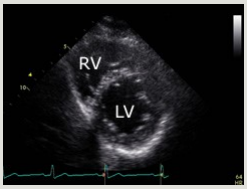
Frank-Startling Mechanism

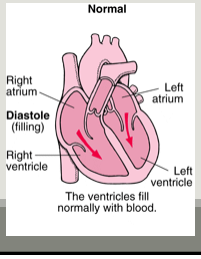


Preload

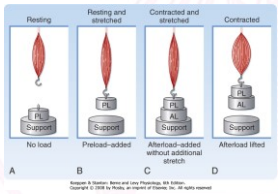
- A load (force/tension) that stretch the muscle before the initiation of contraction

- Myocardial cell length
- LV end diastolic volume --- LV size
- Pressure that streactch the heart
  - End diastolic pressure --- LVEDP
  - Atrial pressure





What is the afterload ?



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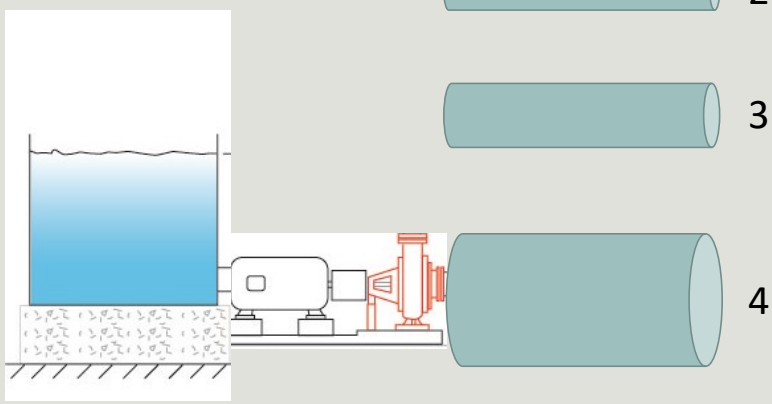
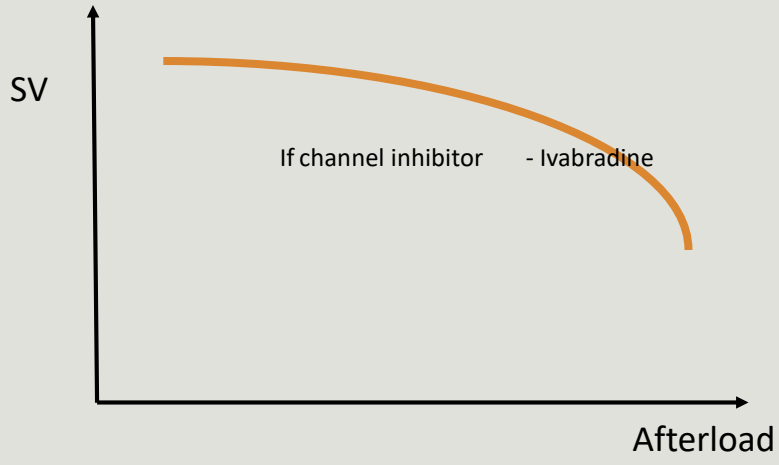
Afterload



Afterload



Afterload in Clinical

A “load” (resistant) that the heart has to contract against

- Vascular resistant
- Systolic blood pressure
- Vaso-constriction
- etc.

What is the contractility ?

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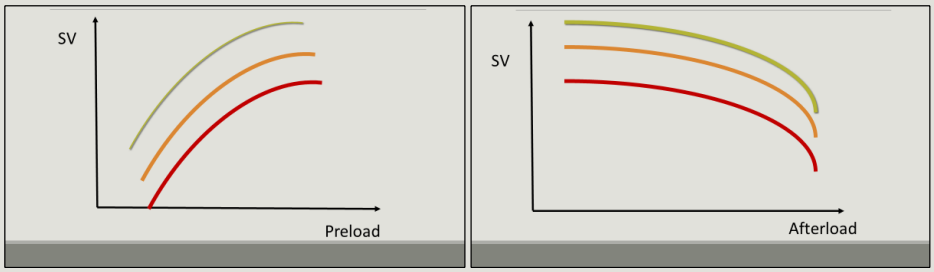
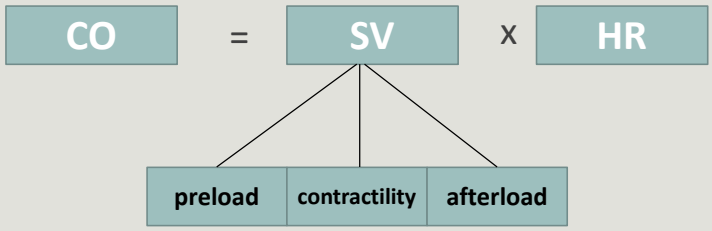
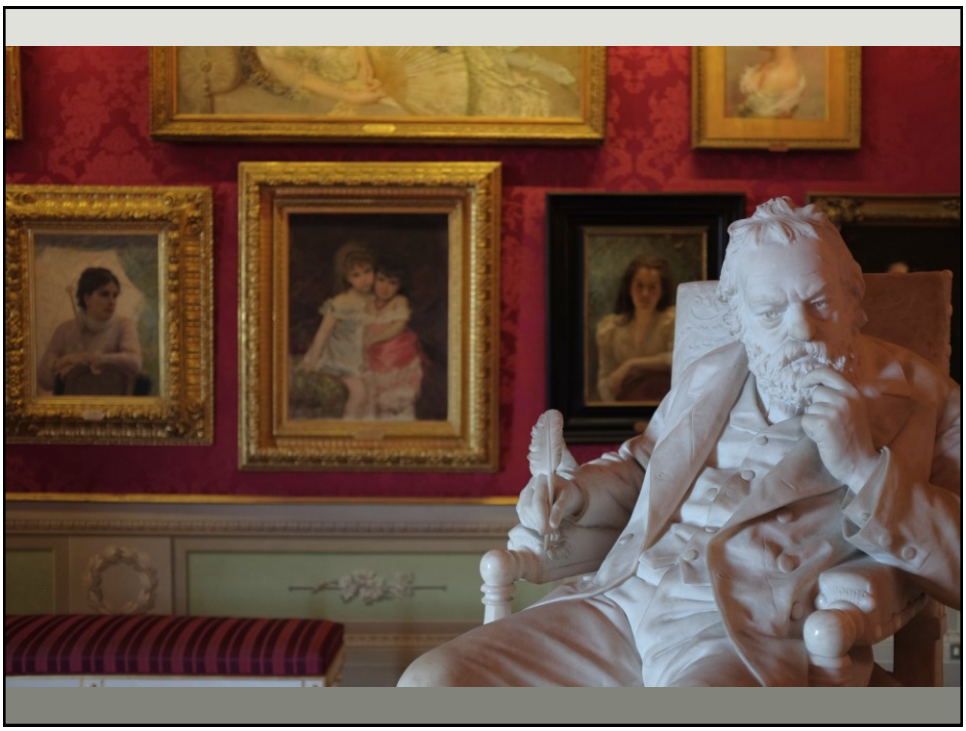
Contractility

An intrinsic property of the myocyte at a giving load

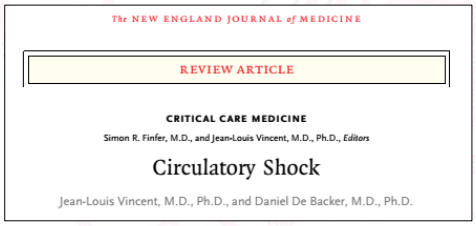


Cardiac output





What is shock?


The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

CRITICAL CARE MEDICINE

Simon R. Finfer, M.D., and Jean-Louis Vincent, M.D., Ph.D., *Editors*

Circulatory Shock

Jean-Louis Vincent, M.D., Ph.D., and Daniel De Backer, M.D., Ph.D.

N Engl J Med 2013; 369:1726-1734

Chulalongkorn HEART FAILURE & TRANSPLANT CARDIOLOGY

What is shock ?

"The clinical syndrome characterize by an inadequate global tissue perfusion."

- Usually have hypotension (MAP < 60 mmHg)

Initiate by various causes

Lead to a vicious cycle of damages, due to

- Cellular dysfunction → functional and structural change.
- Multiple organ failure and death.

Adapt from harrison principles of internal medicine 18th edition

HYPOTENSION
≠
SHOCK

Hypoperfusion: Lead to a vicious cycle of damages

Cellular

- ATP depletion
- Aerobic to anaerobic
- Abnormal membrane function
- Cell dysfunction, swelling, death
- Inflammatory response
- Hematologic response

Multiorgan involments

- Renal failure
  - Acute kidney injury
- Liver failure
  - Ischemic hepatitis, shock liver
- Respiratory distress or failure
- Cardiac depression
- DIC

S&S symptoms of hypoperfusion

Δ mental status

Tachycardia

↓ BP

↓ urine

cold skin

↑Cr

↑Lactic acid

etc

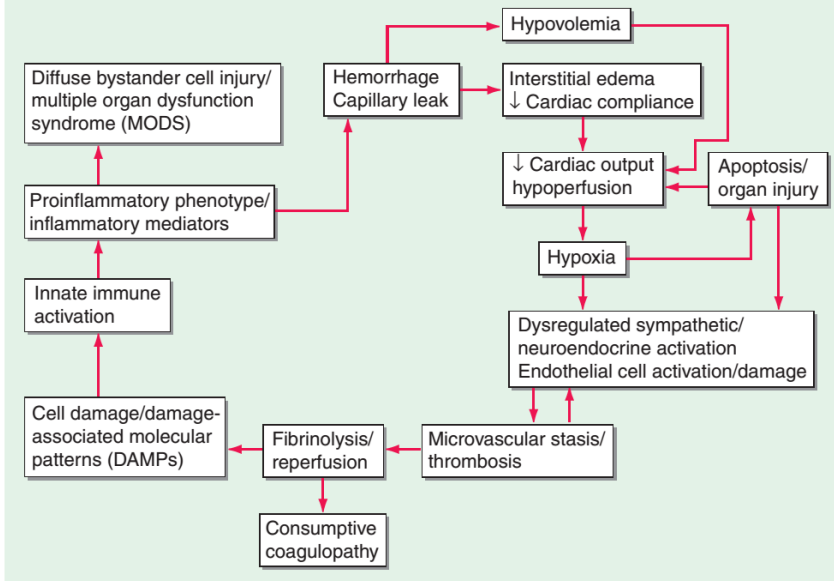
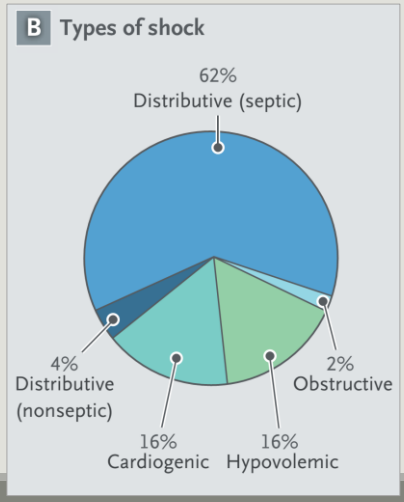


Figure 270-1 Shock-induced vicious cycle.

Initiate by various causes



NEJM 2013

Type of shock
initiation and compensatory mechanism

Type of Shock	Preload	CO	Afterload	Cause
Hypovolemic shock				
Cardiogenic shock				
Distributive shock				
Other type of shocks: Hypoadrenal, neurogenic, obstructive				

Type of shock
initiation and compensatory mechanism

Type of Shock	Preload	CO	Afterload	Cause
Hypovolemic shock				
Cardiogenic shock				
Distributive shock				
Other type of shocks: Hypoadrenal, neurogenic, obstructive				

High preload: ↑ JVP, (+) ascites, edema, (+) crepitations

Low preload: dry mucosa, low JVP, skin turgor, orthostatic hypotension

Type of shock
initiation and compensatory mechanism

Type of Shock	Preload	CO	Afterload	Cause
Hypovolemic shock				
Cardiogenic shock				
Distributive shock				
Other type of shocks: Hypoadrenal, neurogenic, obstructive				

High afterload: cold skin, pale, ↑SVR

Low preload: warm skin, ↑SVR

Type of shock
initiation and compensatory mechanism

Type of Shock	Preload	CO	Afterload	Cause
Hypovolemic shock	↓			
Cardiogenic shock		↓		
Distributive shock			↓	

Other type of shocks: Hypoadrenal, neurogenic, obstructive

Type of shock
initiation and compensatory mechanism

Type of Shock	Preload	CO	Afterload	Cause
Hypovolemic shock	↓	~↑	↑	Blood or fluid loss (internal, external)
Cardiogenic shock	↑	↓	↑	Acute MI, acute HF Arrhythmia, cardiac tamponade pulmonary emboli
Distributive shock	~↓	↑↓	↓	Septic, anaphylaxis, inflammation, toxin

Other type of shocks: Hypoadrenal, neurogenic, obstructive

Treatment

Type of Shock	Preload	CO	Afterload
Hypovolemic shock	↓	~↑	↑
Cardiogenic shock	↑	↓	↑
Distributive shock	~↓	↑↓	↓

Reverse the cause(s)
- In a timely fashion

Support and prevent further end organ damage
- Restore perfusion, reverse the physiology

ICU:

Fluid resuscitation: Crystalloid > colloid, ~~Cardiogenic shock~~

Circulatory support: Inotrope, vasopressor medications, Devices

Ventilation support: O2 support, Mechanical Ventilator/ Endotracheal tube

Invasive monitor: Arterial line, PA catheter (Swan-Ganz), Foley cath

	Action	Usual dose	C[1]	A[2]	Note
Epinephrine	α1 β1 β2	0.01-0.1mcg/kg/min 1 mg iv bolus q 3 mins	↑↑↑↑	↑↑↑	Low dose = more β. (like dobutamine) High dose = more α. (like norepi) Use: ACLS, anaphylaxis, S/E: splanchnic vasoconstrict.
Norepinephrine	α1 β1 β2	0.01-3 mcg/kg/min	↑↑↑	↑↑↑↑	Potent vasoconstriction. Moderate ↑CO. ~HR effect (reflex bradycardia from increased MAP. Use: Septic shock.
Dopamine **Low** **Moderate** **High**	DA α1 β1 β2 DA α1 β1 β2 DA	0.5 - 2 mcg/kg/min 2-10 mcg/kg/min 10-20 mcg/kg/min	~ ↑↑ ↑↑	↓ ↑ ↑↑↑	Precursor to norepi but less α , more β effect. Dose-dependent effects. Dose is varied pt to pt. Use: Septic shock, 2nd-line alternative to norepinephrine.
Dobutamine	β1 β2 (α1)	2- 20 mcg/kg/min	↑↑	↓↓	Not a vasopressor. Inotrope with a vasodilation. The net effect = ↑CO + ↓SVR, may not ↓ BP. Use: HF, cardiogenic.
Milrinone	PDE inh	0.375 – 0.75 mcg/kg/min	↑↑	↓↓↓	Similar to dobutamine more vasodilator, ↓PA Use: HF, cardiogenic.
Isoproterenol	β1 β2	2-10 mcg/min	↑	↓↓↓	Prominent chronotropic. Prominent vasodilation. Use: Bradycardia
Phenylephrine	α1	0.5-10 mcg/kg/min	0	↑↑↑	Pure vasoconstriction. May decrease SV.
Vasopressin	V_1	0.04 unit/min	0	↑↑↑	Pure vasoconstriction. Use: 2nd -line in refractory vasodilatory shock. . S/E: coronary, mesenteric ischemia, skin necrosis. ↓Na and pulm vasoconstriction

Sample

A 55 yo M with hx of HTN, DM presents with "crushing" substernal CP, diaphoresis, hypotension, tachycardia and cool, clammy extremities

An 81 yo F from a nursing home presents to the ED with altered mental status. She is febrile to 39.4, hypotensive with a widened pulse pressure, tachycardic, with warm extremities

A 68 yo M with hx of HTN and DM presents to the ER with abrupt onset of diffuse abdominal pain with radiation to his low back. The pt is hypotensive, tachycardic, afebrile, with cool but dry skin

Cause of Hypovolemic Shock

- Non-hemorrhagic
  - Vomiting
  - Diarrhea
  - Neglect, environmental (dehydration)
  - Bowel obstruction, pancreatitis
  - Burns
- Hemorrhagic
  - GI bleed
  - Trauma
  - Massive hemoptysis
  - AAA rupture
  - Ectopic pregnancy, post-partum bleeding

Cause of Septic shock

Most common type of shock

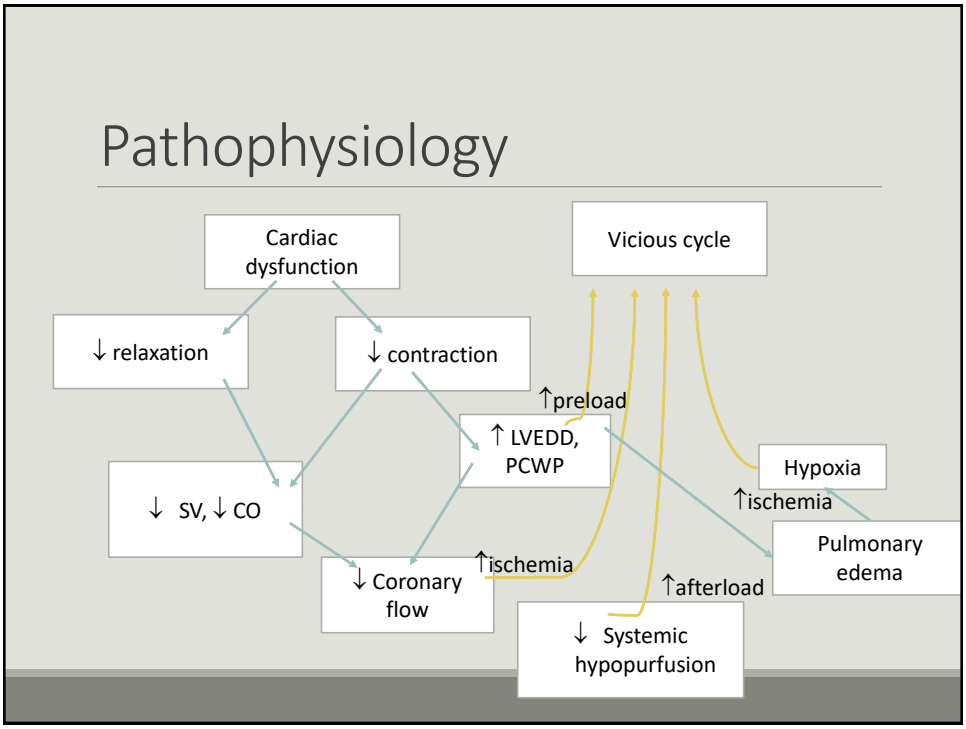
Hypoperfusion + infection + 2 SIRS (systemic inflammatory response syndrome) criteria

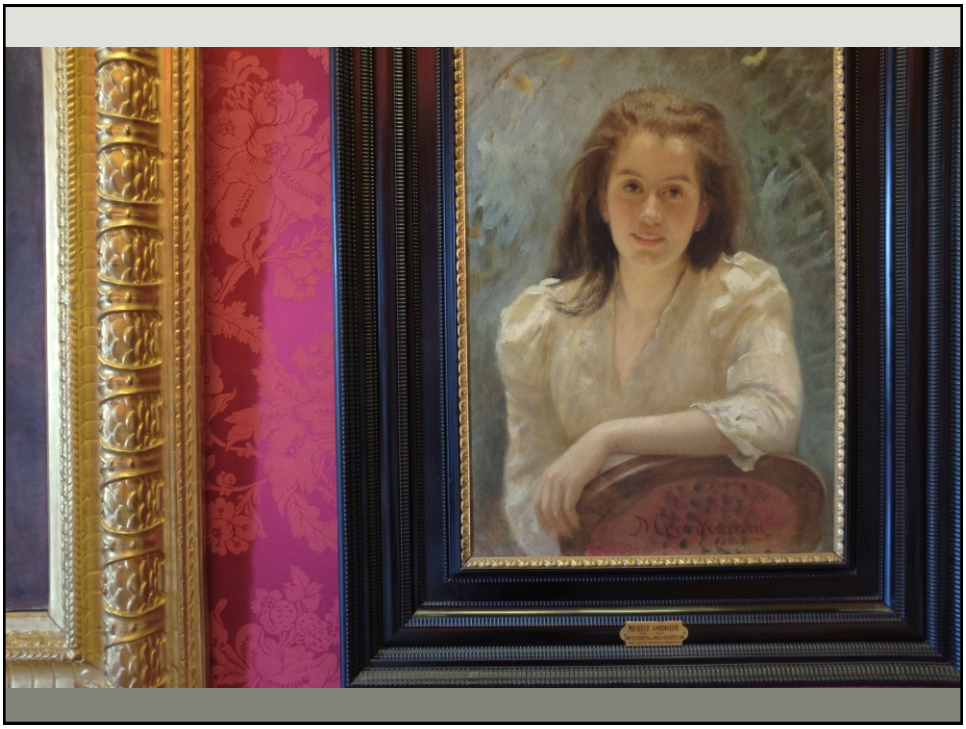
- S&S of hypoperfusion
- Temp > 38 or < 36 C
- HR > 90
- RR > 20
- WBC > 12,000 or < 4,000
- Plus the presumed existence of infection

Cause of cardiogenic shock

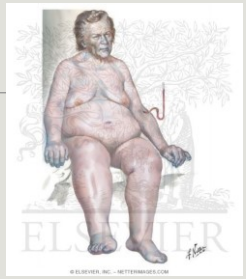
Etiologies of Cardiogenic Shock or Pulmonary Edema
Acute myocardial infarction/ischemia
LV failure
VSR
Papillary muscle/chordal rupture—severe MR
Ventricular free wall rupture with subacute tamponade
Post-cardiac arrest
Post-cardiotomy
Refractory sustained tachyarrhythmias
Acute fulminant myocarditis
End-stage cardiomyopathy
Left ventricular apical ballooning
Takotsubo's cardiomyopathy
Hypertrophic cardiomyopathy with severe outflow obstruction
Aortic dissection with aortic insufficiency or tamponade
Pulmonary embolus
Severe valvular heart disease
Critical aortic or mitral stenosis
Acute severe aortic or MR
Toxic-metabolic
Beta-blocker or calcium channel antagonist overdose
Other Etiologies of Cardiogenic Shock[b]
RV failure due to:
Acute myocardial infarction
Acute coronary pulmonale
Refractory sustained bradyarrhythmias
Pericardial tamponade
Toxic/metabolic
Severe acidosis, severe hypoxemia

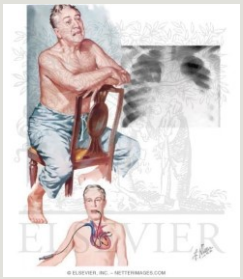
Pathophysiology





Heart failure





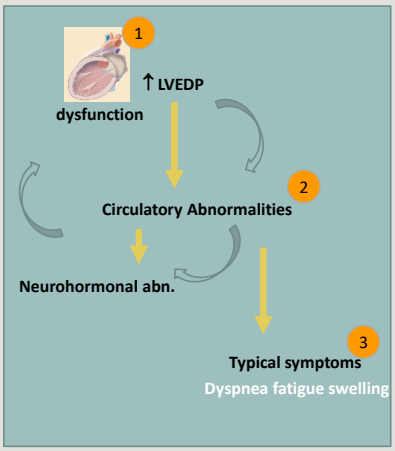
Definition of HF

1. A syndrome caused by cardiac abnormality
2. Leads to circulatory abnormalities and neurohormonal abnormality
3. Resulting in typical symptoms of
   - Congestion
   - Poor perfusion

a. Common pathway from any cardiac injury

b. Progressive, remodeling

c. Vicious cycle from maladaptation



Cause of HF

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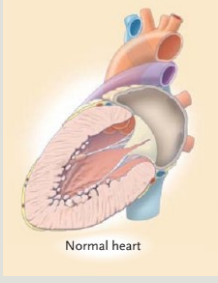
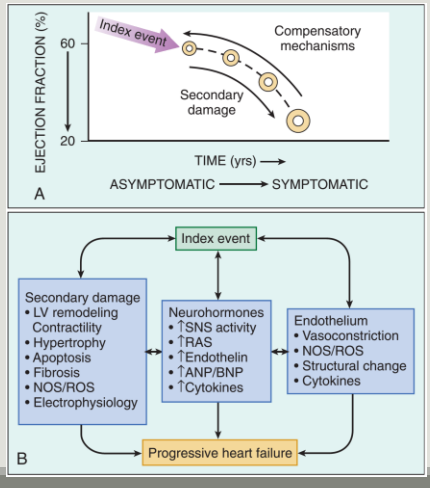
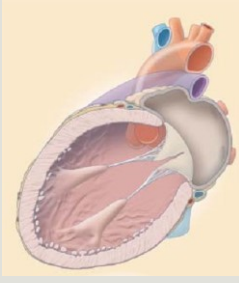
Circulation. 2013;128:e240-e327.

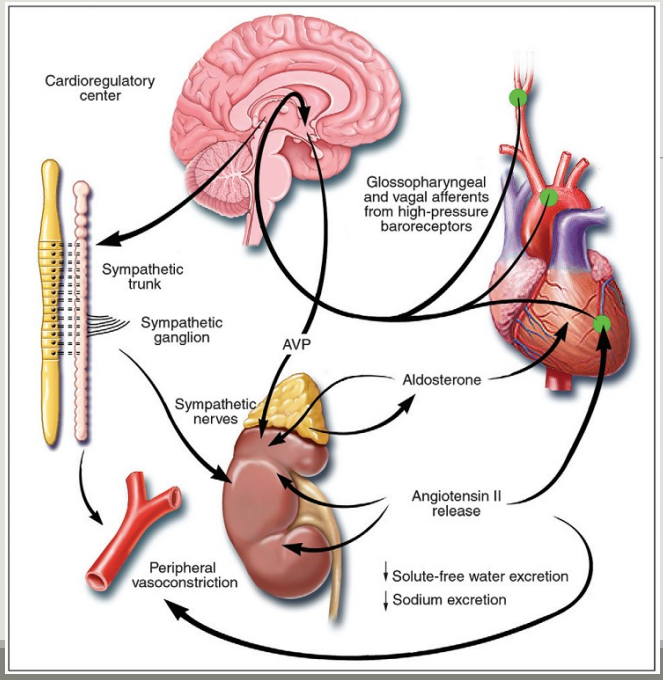
Pathophysiology
Remodeling

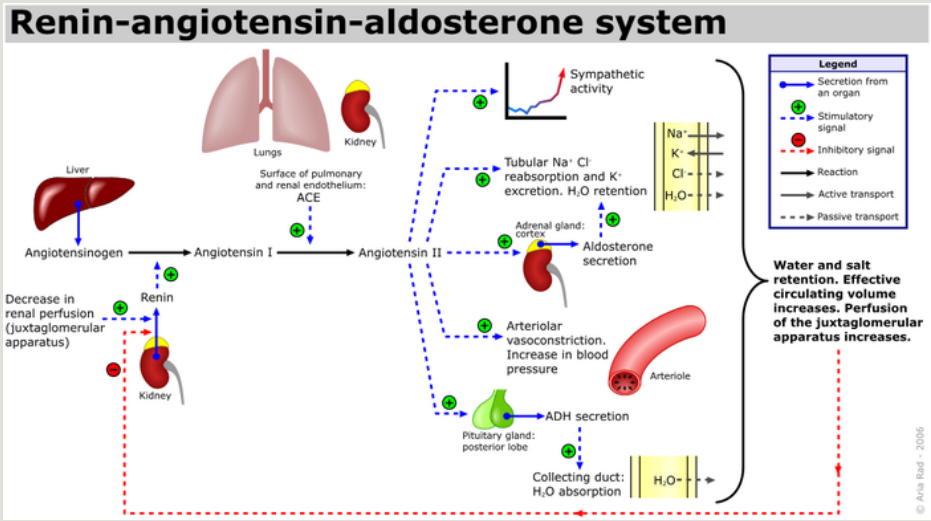


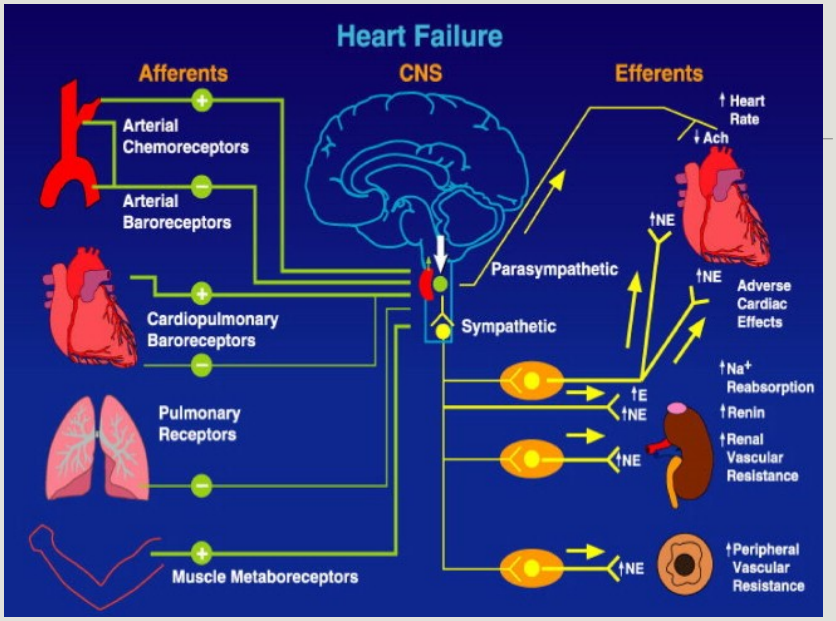
Normal heart






Cardioregulatory center
Glossopharyngeal and vagal afferents from high-pressure baroreceptors
Sympathetic trunk
Sympathetic ganglion
AVP
Aldosterone
Sympathetic nerves
Angiotensin II release
Peripheral vasoconstriction
Solute-free water excretion
Sodium excretion


Renin-angiotensin-aldosterone system
Lungs
Kidney
Liver
Surface of pulmonary and renal endothelium: ACE
Angiotensinogen
Angiotensin I
Angiotensin II
Renin
Decrease in renal perfusion (juxtaglomerular apparatus)
Kidney
Sympathetic activity
Tubular Na+ Cl- reabsorption and K+ excretion. H2O retention
Na+
K+
Cl-
H2O
Adrenal gland: cortex
Aldosterone secretion
Arteriolar vasoconstriction. Increase in blood pressure
Arteriole
ADH secretion
Pituitary gland: posterior lobe
Collecting duct: H2O absorption
H2O
Legend
Secretion from an organ
Stimulatory signal
Inhibitory signal
Reaction
Active transport
Passive transport
Water and salt retention. Effective circulating volume increases. Perfusion of the juxtaglomerular apparatus increases.
© Ania Rad - 2006



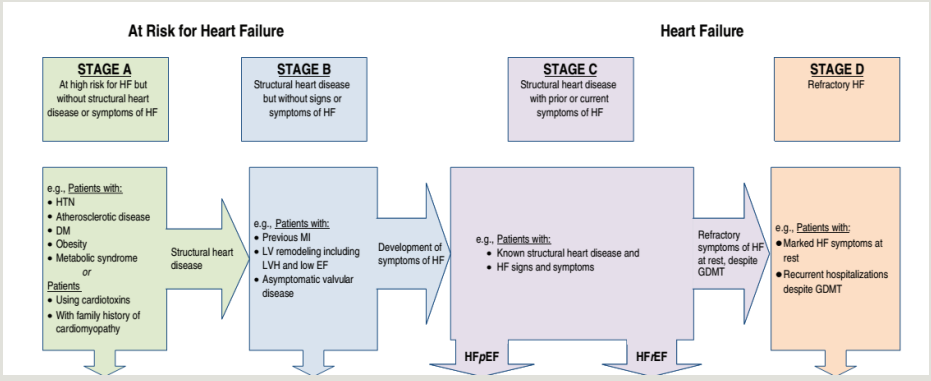
J Am Coll Cardiol 2009;54:375–85.

The result of Adverse remodeling

TABLE 25-2 Overview of Left Ventricular Remodeling

Alterations in Myocyte Biology
Excitation-contraction coupling
Myosin heavy chain (fetal) gene expression
Beta-adrenergic desensitization
Hypertrophy
Myocytolysis
Cytoskeletal proteins
Myocardial Changes
Myocyte loss
Necrosis
Apoptosis
Autophagy
Alterations in extracellular matrix
Matrix degradation
Myocardial fibrosis
Alterations in Left Ventricular Chamber Geometry
LV dilation
Increased LV sphericity
LV wall thinning
Mitral valve incompetence

Stage of HF



Classification of HF

Chronicity Acute Chronic	Stage A, B, C, D	EF rEF (< 40%) pEF (≥ 50%) mrEF (40-50)	Hemodynamic profile Wet - Dry Cold - warm
NYHA fn class I, II, III, IV	Etiology Ischemic cause Non-ischemic cause	involvement LV RV Both	phenotype Dilated Hypertrophic Restrictive
Endo / myo / epi	Backward / Forward failure	Low / High output	Systolic / diastolic failure

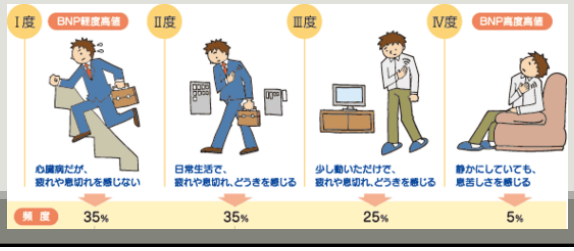
S&S of HF

Non-specific

Dyspnea from increased breathing drive
- Reduction in exercise capacity (NYHA II-IV)
- Orthopnea, PND

Wt gain, leg swollen, fatigue, early satiety, N/V, confusion

Apical shift, S3, S4, ↑ JVP, (+) HJR, crepitations, ascites, edema



Treatment

Treat the cause

Self-care
- weight monitor, ↓ salt intake

Diuretics to control volume status

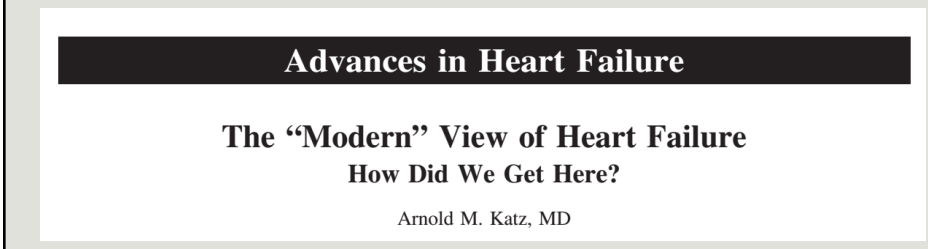
Treatment: Chronic

Chronic
- Betablocker
- ACE / ARB
- Aldosterone blocker - spironolactone
- Angiotensin receptor, neprilysin inhibitor(ARNI) - Valsartan/sacubitril
- Other meds: Ivabradine, HDZ, ISDN, dignoxin
- CRT - Cardiac resynchronize therapy (special pacemaker)
- ICD - Implantable cardioverter Defibrillator

Acute

Aggressive diuresis, vasodilator, inotrope

End-staged HF
- Heart transplant, mechanical circulatory support, palliative care


Advances in Heart Failure

The "Modern" View of Heart Failure
How Did We Get Here?

Arnold M. Katz, MD

Circ Heart Fail.2008;1:63-71

Thank you

Aekarach.a@chula.ac.th



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