6 September 2016

Pathophysiology of Cardiogenic Shock & Heart Failure

เอกราช อริยะชัยพาณิชย์

Heart Failure and Transplant Cardiology

aekarach.a@chula.ac.th

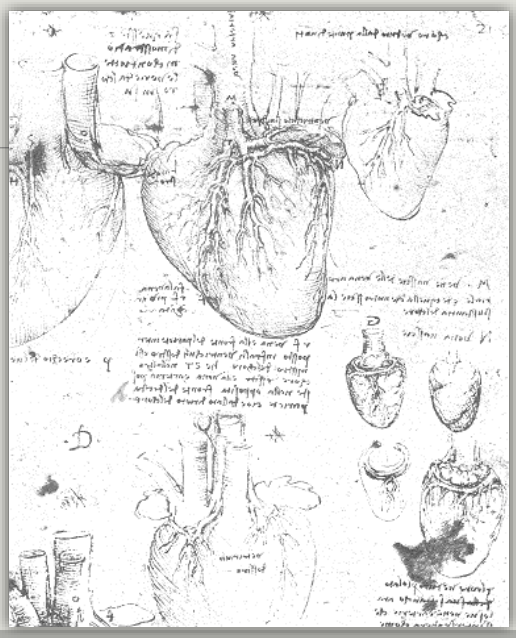
Agenda

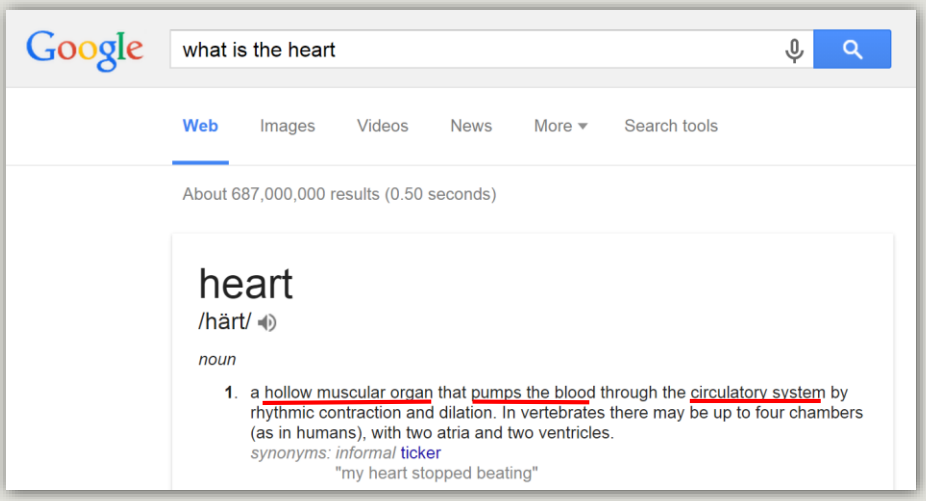
- Cardiac physiology
- Pathophysiology of shock
- Pathophysiology of heart failure

http://fullpulse.weebly.com/conversation

Cardiovascular system

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





The cardiovascular system

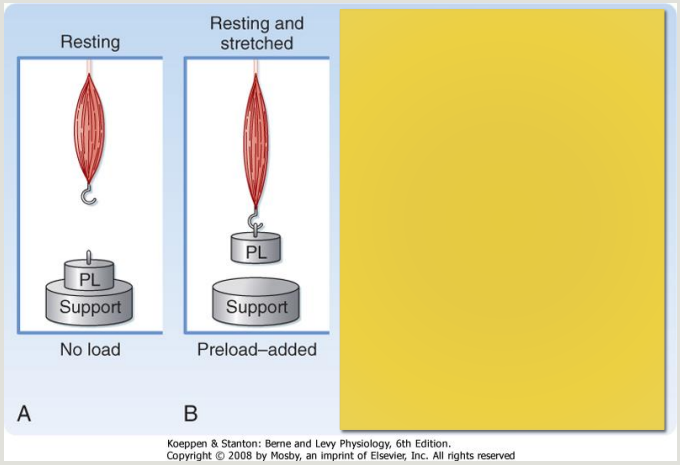
Cardiac output (CO)

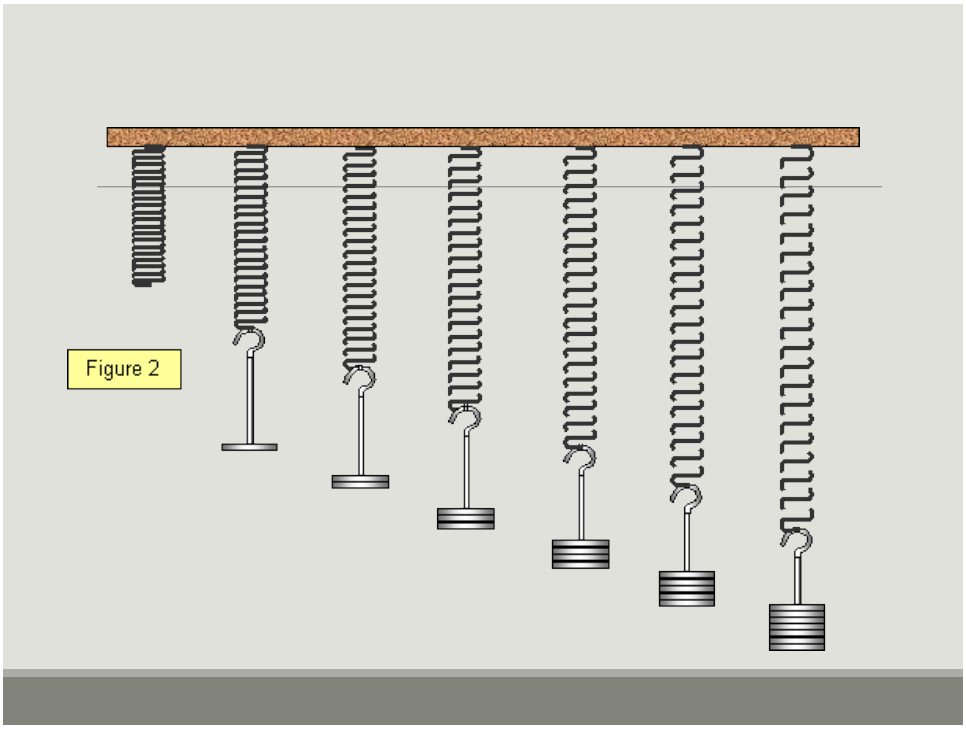
- The blood flow thru the heart in 1 minute
- L/min
- **Stroke volume x Heart rate**

Intrinsic heart mechanics properties

- Preload // Contractility // Afterload

What is preload ?





Preload

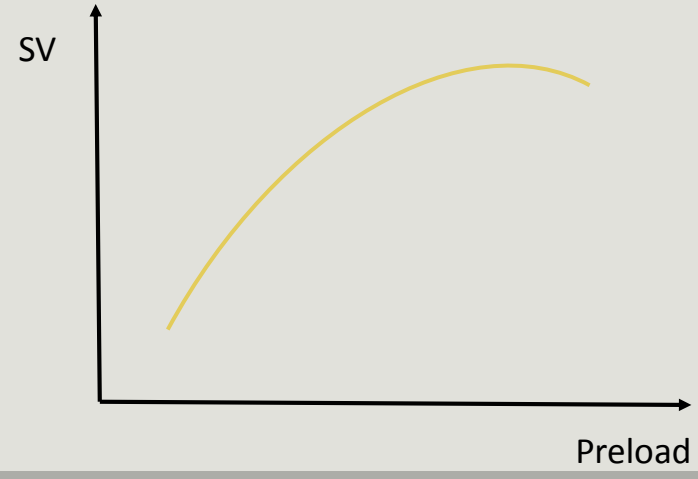
1

2

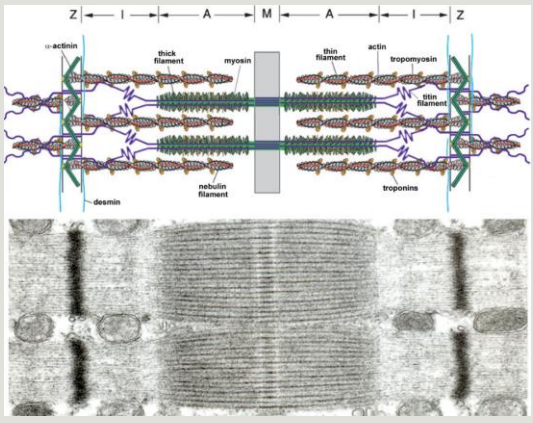
3

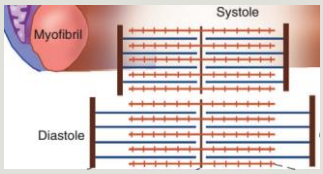
4

Frank-Startling Mechanism



Preload:
Cellular level





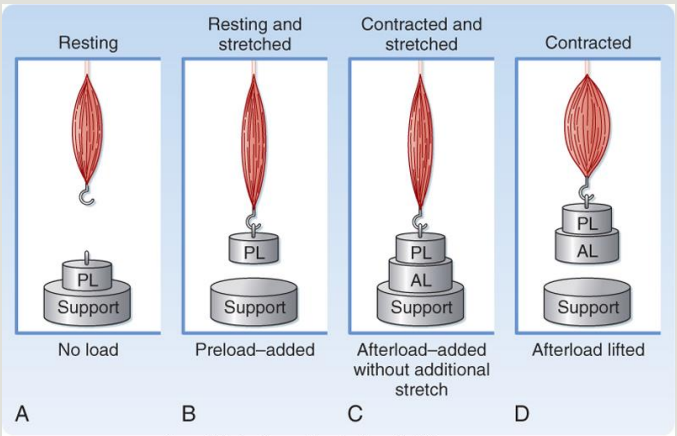
Preload in clinical

A "load" to the contractile unit before contraction

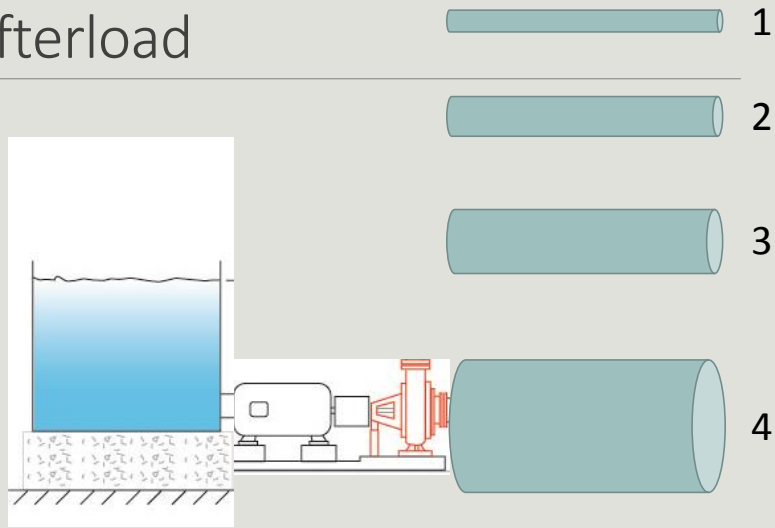
- A load =

Molecular Cellular	z-z line contractile protein myocardial cell length
Heart	Wall stress
	LV end diastolic pressure --- LVEDP
	LV end diastolic volume --- LV size
	RA pressure --- JVP
	Volume status

What is afterload ?



Afterload



Afterload

Afterload in Clinical

A “load” that the heart has to contract against

- Systolic blood pressure
- Systolic vascular resistant
- vaso-constriction

What is shock ?

What is shock ?

"The clinical syndrome from various causes that result in damages due to inadequate global tissue perfusion."

- Inadequate O2 delivery
- Usually have hypotension (MAP < 60 mmHg)

Lead to a vicious cycle, due to

- Organ protective mechanism
- Cellular dysfunction → functional and structural change.

multiple organ failure and death.

Adapt from harrison principles of internal medicine 18th edition

HYPOTENSION
≠
SHOCK

Hypoperfusion: Cellular responses

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

Hypoperfusion: Autonomic responses

- Sympathetic nervous system
  - Baroreceptor, adrenal gland
  - NE, epinephrine, dopamine, and cortisol release
  - Vasoconstriction, ↑ HR, ↑ contractility, ↑ BP
- Renin-angiotensin-aldosterone system
  - Water and Na absorption, vasoconstriction
  - ↑ blood volume and ↑ BP
- ADH (vasopressin), cortisol,

Multi organ dysfunction

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

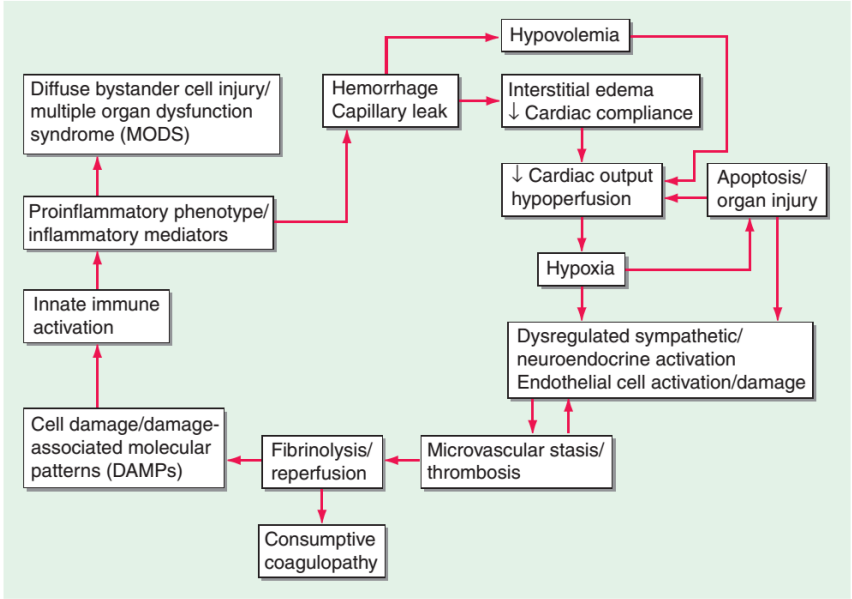
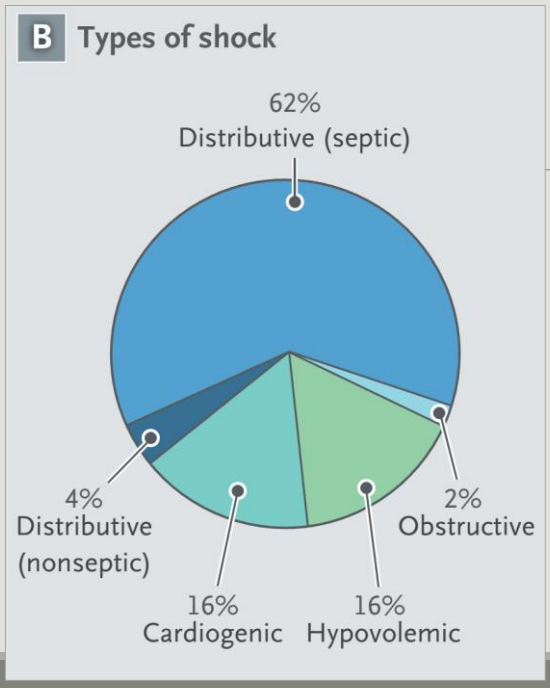


Figure 270-1 Shock-induced vicious cycle.

How many type of shock are there ?



NEJM 2013

Type of shock

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

Type of shock

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

Type of shock

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

Type of shock

JVP
Central venous pressure
Pulmonary capillary pressure
Sign of hypovolumia

Type of Shock	Preload	CO	Afterload	Cause
Hypovolemic	↓	~↑	↑	Blood or fluid loss (internal, external)
Cardiogenic	↑	↓	↑	
Distributive	~↓	↑↓	↓	Septic, anaphylaxis, inflammation, toxin
Other type of shocks: hypoadrenal, neurogenic, obstructive				

Warm vs. cold skin
pale
Systemic vascular resistant

S&S symptoms of hypoperfusion

Δ mental status

Tachycardia

↓ BP

↓ urine

cold skin

↑Cr, ↑Lactic acid.

Treatment

Recognize shock

Reverse the cause(s)
- In a timely fashion

Support and prevent further end organ damage
- Restore perfusion

ICU:

Invasive monitor: Arterial line, foley cath, PA catheter (Swann-Ganz)

Ventilation support: O2 support, Mechanical Ventilator/ Endotracheal tube

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

Hemodynamic support: Inotrope, pressor, VAD

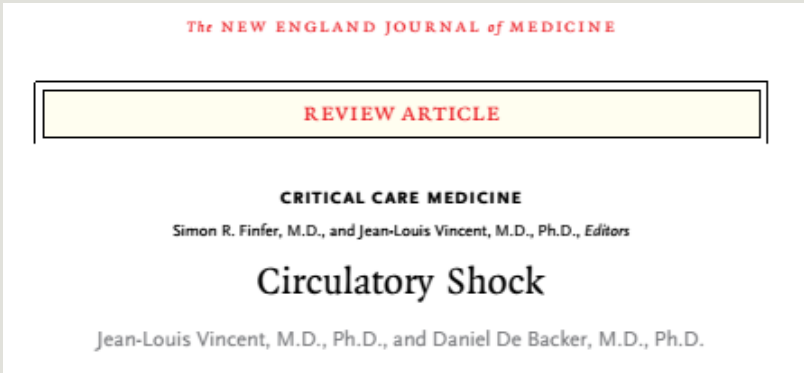
	Action	Usual dose	C[1]	A[2]	Note
Epinephrine	α1 β1 β2	0.01-0.1mcg/kg/min 1 mg iv bolus q 3 mins	↑↑↑↑	↑↑↑	Low dose = more β. (like dobutamine) High dose = more α. (like norepi) Use: ACLS, anaphylaxis, S/E: splanchnic vasoconstrict.
Norepinephrine	α1 β1 β2	0.01-3 mcg/kg/min	↑↑↑	↑↑↑↑	Potent vasoconstriction. 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


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

Cause of Hypovolemic Shock

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

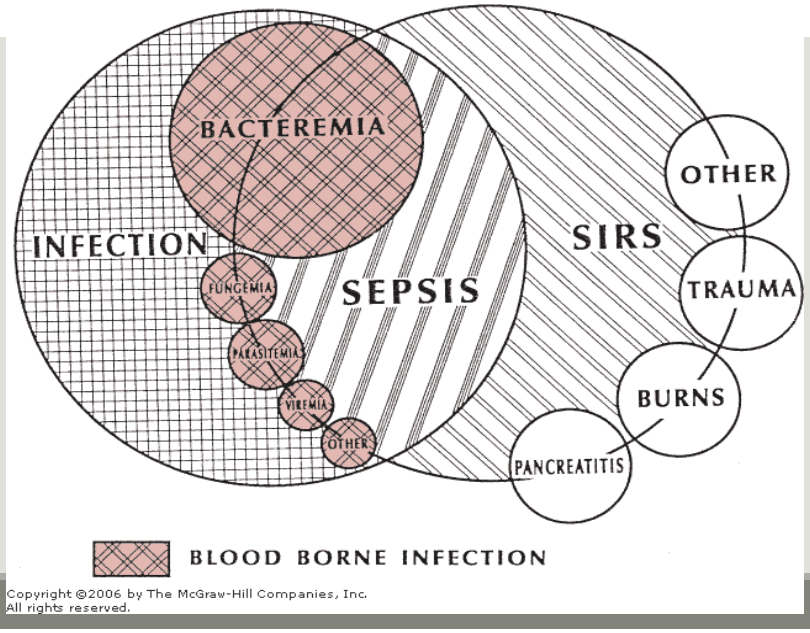
Cause of Septic shock

Another lecture by it self

Most common type of shock

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

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



Cardiogenic shock

Hypoperfusion due to low cardiac output

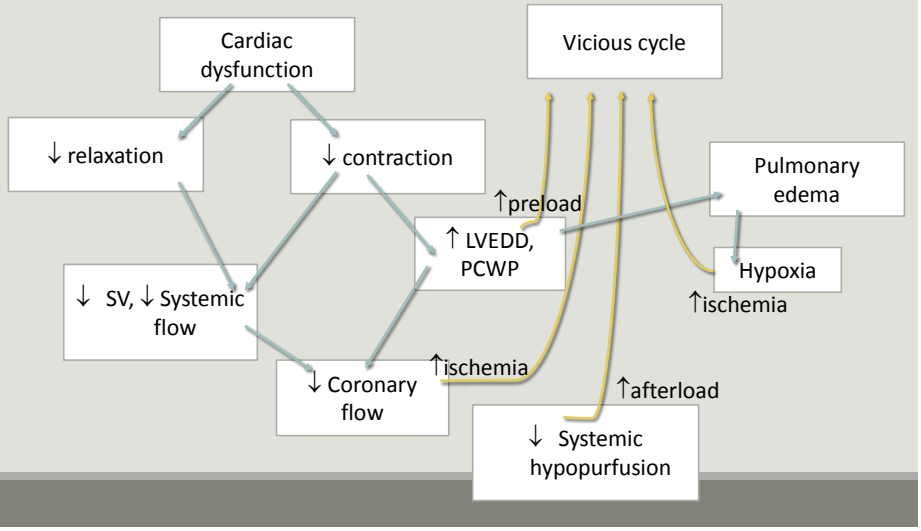
- Low BP, high PCWP
- SBP < 90 mmHg
- CI < 2.2 L/m/m^2
- PCWP > 18 mmHg

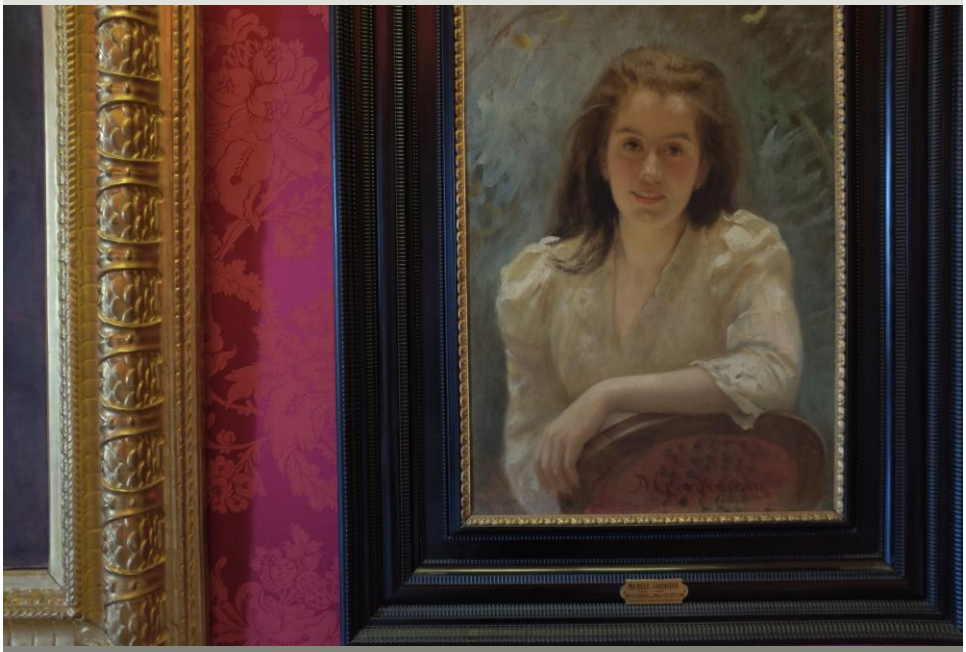
50% mortality rate

TABLE 272-1 Etiologies of Cardiogenic Shock (CS)[a] and Cardiogenic Pulmonary Edema

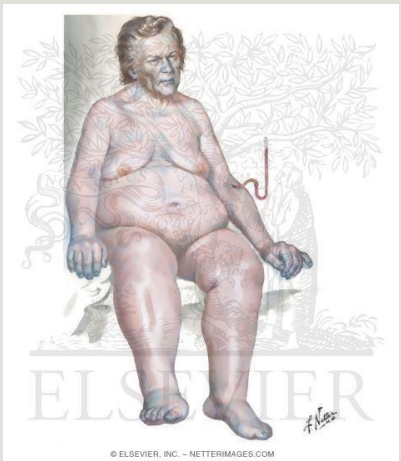
Etiologies of Cardiogenic Shock or Pulmonary Edema
Acute myocardial infarction/ischemia
LV failure
VSR
Papillary muscle/chordal rupture—severe MR
Ventricular free wall rupture with subacute tamponade
Post-cardiac arrest
Post-cardiotomy
Refractory sustained tachyarrhythmias
Acute fulminant myocarditis
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

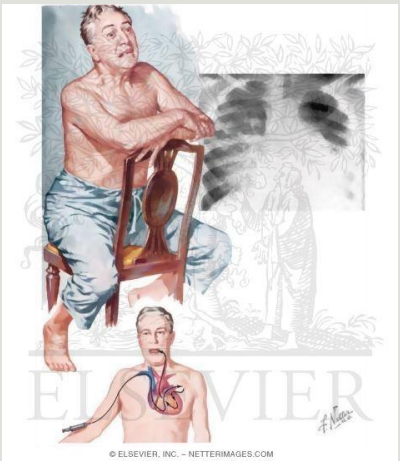
Pathophysiology





Heart failure





HF is a syndrome caused by cardiac dysfunction, generally resulting from myocardial muscle dysfunction or loss and characterized by either LV dilation or hypertrophy or both. Whether the dysfunction is primarily systolic or diastolic or mixed, it leads to neurohormonal and circulatory abnormalities, usually resulting in characteristic symptoms such as fluid retention, shortness of breath, and fatigue, especially on exertion. In the

spontaneously or as a consequence of therapy. In physiologic terms, HF is a syndrome characterized by either or both pulmonary and systemic venous congestion and/or inadequate peripheral oxygen delivery, at rest or during stress, caused by cardiac dysfunction.

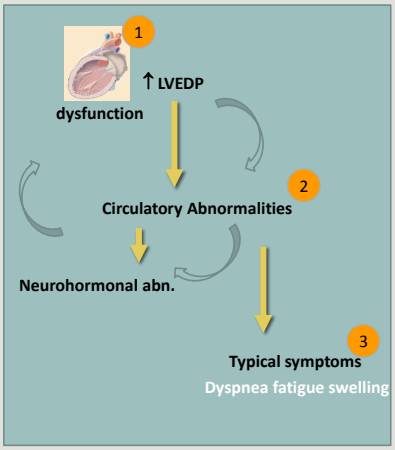
Definition of HF

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

a. Common pathway from any causes

b. Progressive, vicious cycle

c. Systemic maladaptation

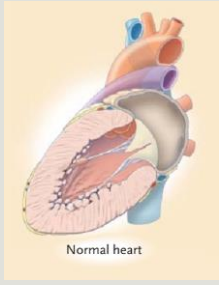


Cause of HF

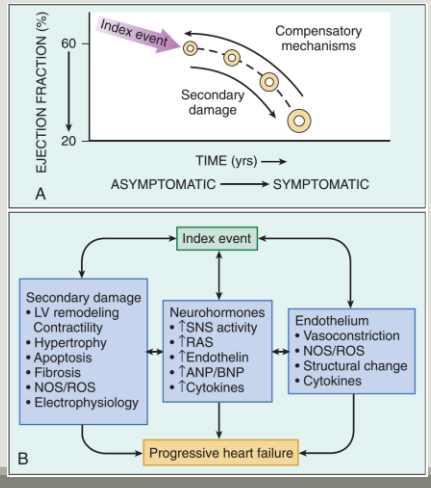
Table of Contents

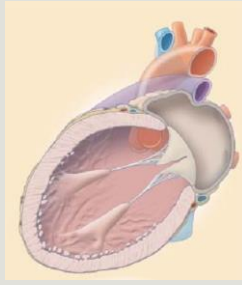
Circulation. 2013;128:e240-e327.

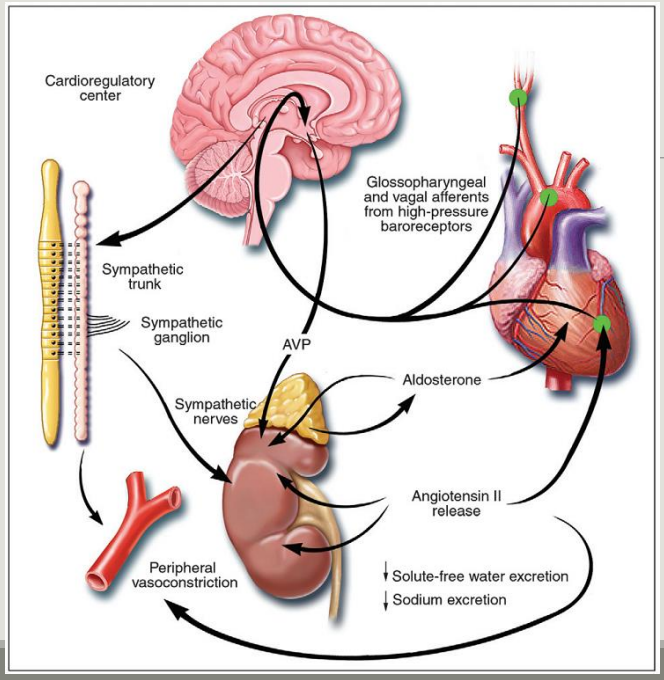
Pathophysiology

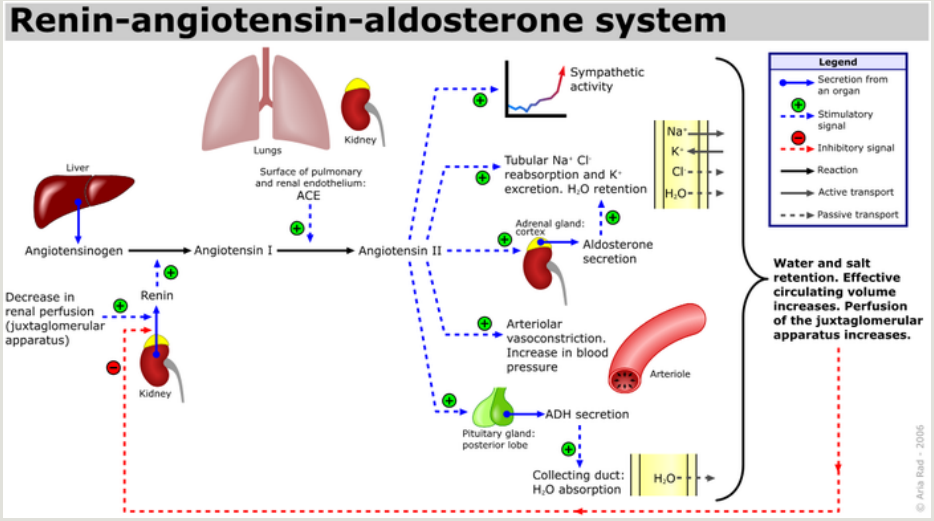


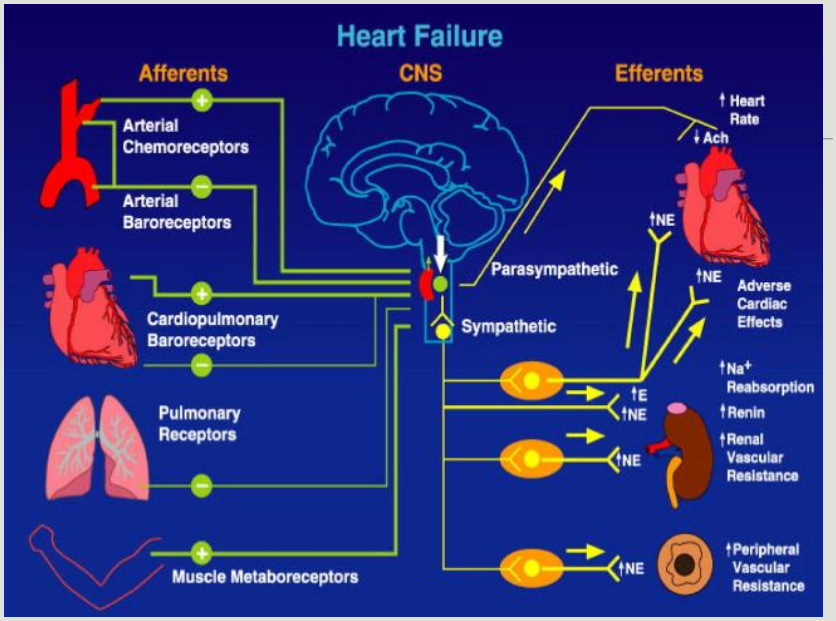
Normal heart






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.

TABLE 25-2 Overview of Left Ventricular Remodeling

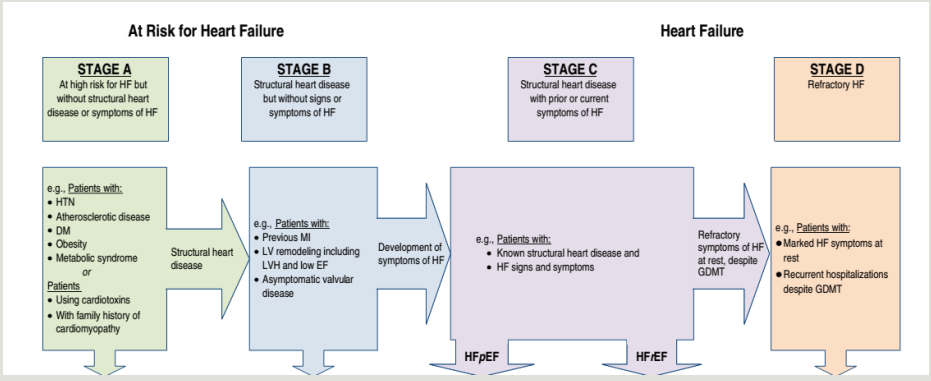
Alterations in Myocyte Biology
Excitation-contraction coupling
Myosin heavy chain (fetal) gene expression
Beta-adrenergic desensitization
Hypertrophy
Myocytolysis
Cytoskeletal proteins

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



S&S of HF

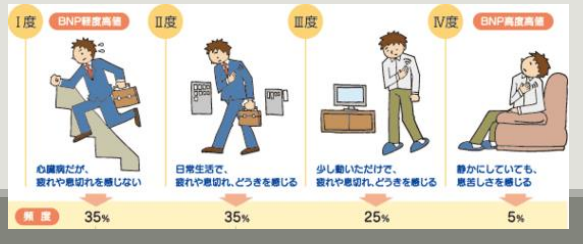
Non specific, fatigue

Dyspnea from increased breathing drive

- Reduction in exercise capacity (NYHA II-IV)
- Orthopnea, PND

Edema, ascites, early satiety, N/V, confusion

Apical shift, S3, S4, ↑ JVP, (+) HJ reflux, ascites, crepitation, edema



Treatment

Self-care
- weight monitor, ↓ salt intake

Diuretics to control symptoms

Treatment

To improve survival
- Betablocker
- ACE inhibitor or Angiotensin receptor blocker (ARB)
- Aldosterone blocker - spironolactone
- If channel inhibitor - Ivabradine
- Angiotensin receptor, neprilysin inhibitor(ARNI) - Valsartan/sacubitril
- Cardiac resynchronize therapy (special pacemaker)
- Implantable cardioverter Defibrillator

End-stage HF
- Heart transplant
- Mechanical circulatory support
- Inotrope
- 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

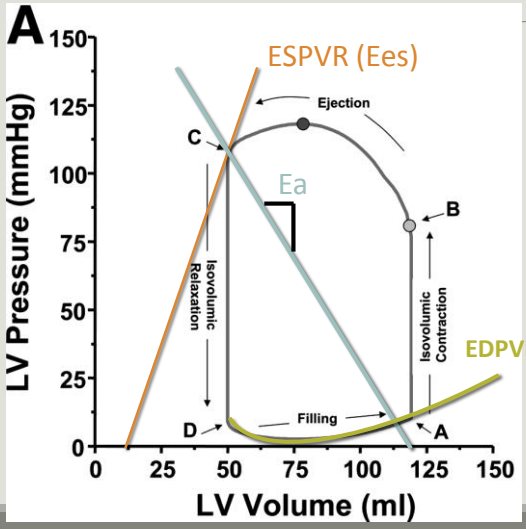
Aekarach.a@chula.ac.th

Chulalongkorn HEART FAILURE & TRANSPLANT CARDIOLOGY

Back up slide

Chulalongkorn HEART FAILURE & TRANSPLANT CARDIOLOGY

Pressure volume Loop of the LV



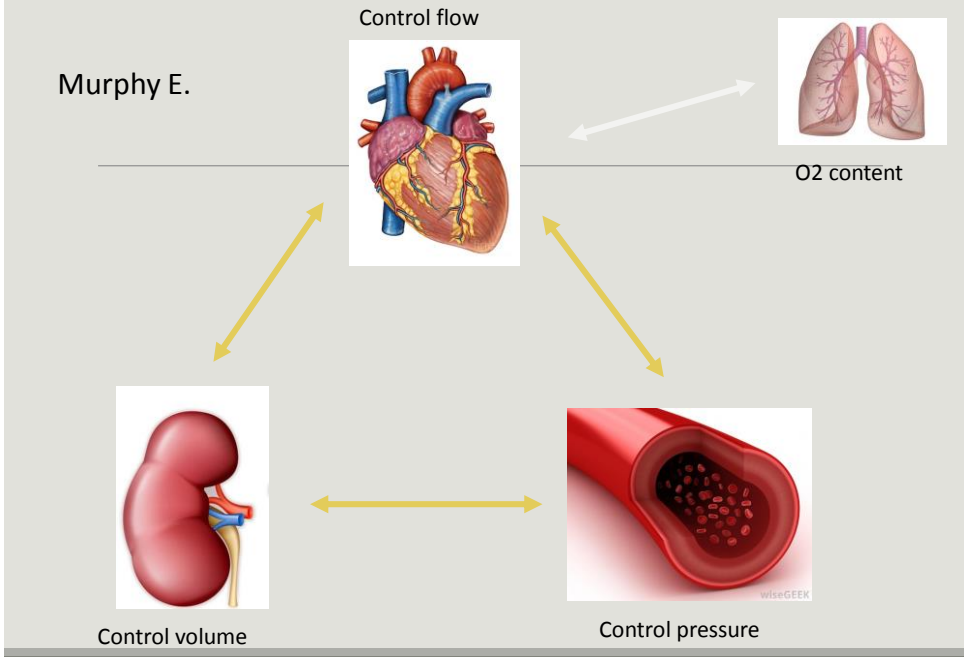
A: MV close
B: AV open
C: AV close
D: MV open

Ees: end-systolic elastance (ESPVR: End systolic PV Relationship)

Ea: Arterial elastance

EDPVR: End diastolic PV Relationship

Murphy E.



Investigation

Lab: shock
- Cr, AST/ALT, WBC, acidosis
- Troponin

ECG:
- MI: ST elevation, Q wave, TW inversion

CXR: pulmonary edema

Echocardiogram: function, etiology

Pulmonary catheter (Swan-Ganz):
- DDx type of shock, intracardiac pressure, CO

Coronary angiogram