Cardiovascular physiology

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Cardiac output

DEFINATION

- Cardiac output : vol of blood pumped by heart per minute. It is measure of ventricular systolic function.

$$C.O = S V \times H R$$

- Stroke volume: vol of blood pumped per contraction

- Cardiac index : C I = C O / BSA

  normal value 2.5 to 4.2 l / min / m^2

DETERMINANTS OF C .O

- Intrinsic factors
  - Heart rate
  - Contractility
- Extrinsic factors
  - Pre load
  - After load

Heart rate

- No of beats per minute
- C .O directly proportional to HR
- HR is intrinsic function of SA node
- HR is modified by autonomic, humoral, local factors
- Enhanced vagal activity decrease HR
- Enhanced sympathetic activity increase HR

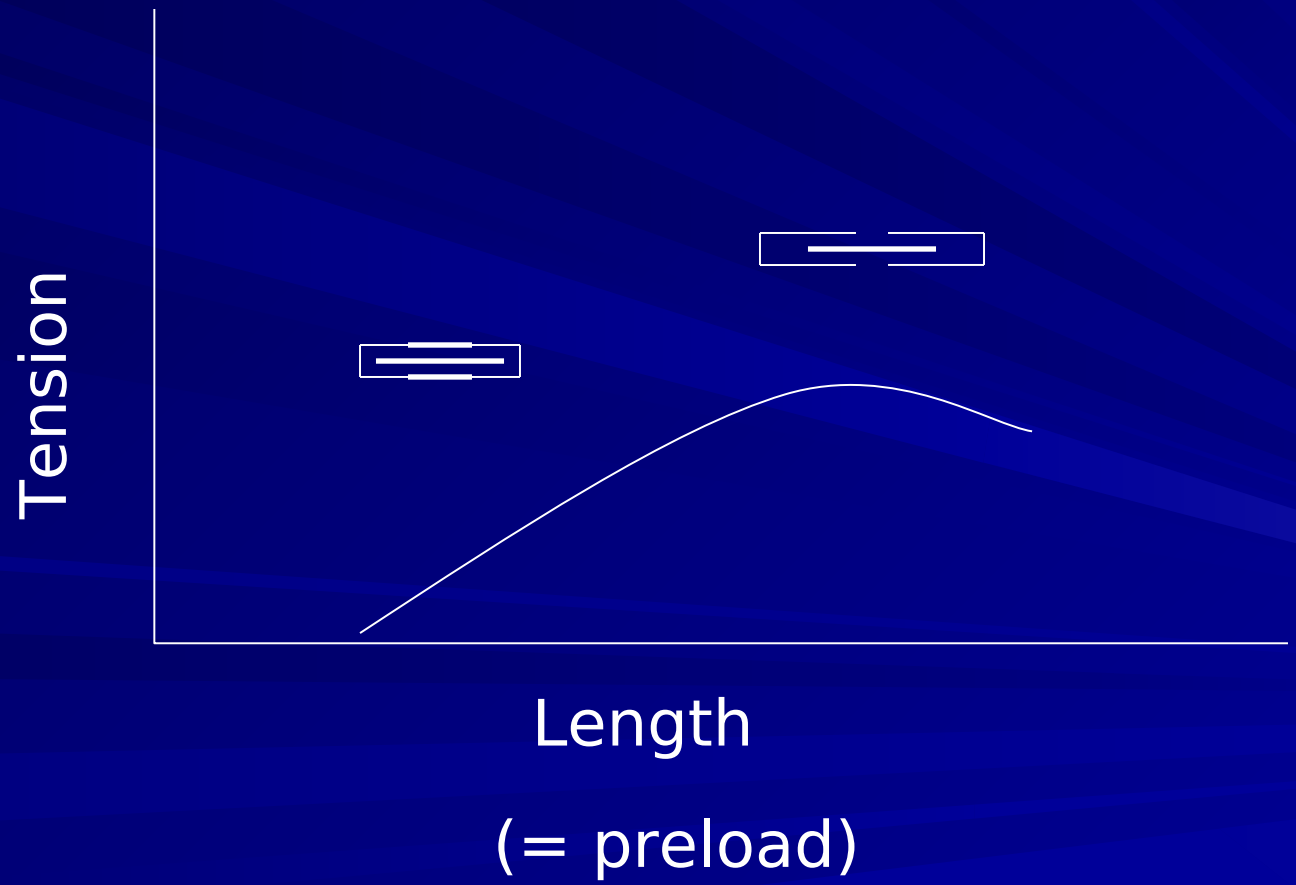
Contractility

- Intrinsic ability of myocardium to pump in absence of changes in preload and after load
- Factors modifying contractility are exercise, adrenergic stimulation, changes in Ph, temperature, drugs, ischemia anoxia.

Frank starling relationship

- Relation between sarcomere length and myocardial force
- States that if cardiac muscle is stretched it develops greater contractile tension
- Increase in venous return increases contractility and CO
- Clinical application is relation between LVEDV and SV

Frank straling relationship



HOW TO ASSESS CONTRACTILITY ?

- Pressure volume loops
- Noninvasive like echocardiography, vetriculography

$$EF = (LVEDV - LVESV)/ LVEDV$$

NORMAL – 60 ± 6%

PRELOAD

- Defined as ventricular load at the end of diastole before contraction has started
- In clinical practice PCWP or CVP are used to estimate preload

Determinants of preload

- Venous return
- Blood volume
- Heart rate
- Atrial contraction

AFTERLOAD

- Defined as systolic load on LV after contraction has began
- Aortic compliance is determinant of afterload e.g. AS or chronic hypertension both impede ventricular ejection
- Measurement of afterload DONE BY

  echocardiography

  systolic BP or SVR

AFTERLOAD

- Wall stress: Laplace law states that wall stress is product of pressure and radius divided by wall thickness

$$\text{wall stress} = P \times R / 2H$$

- RV load depends on PVR.

CARDIAC WORK

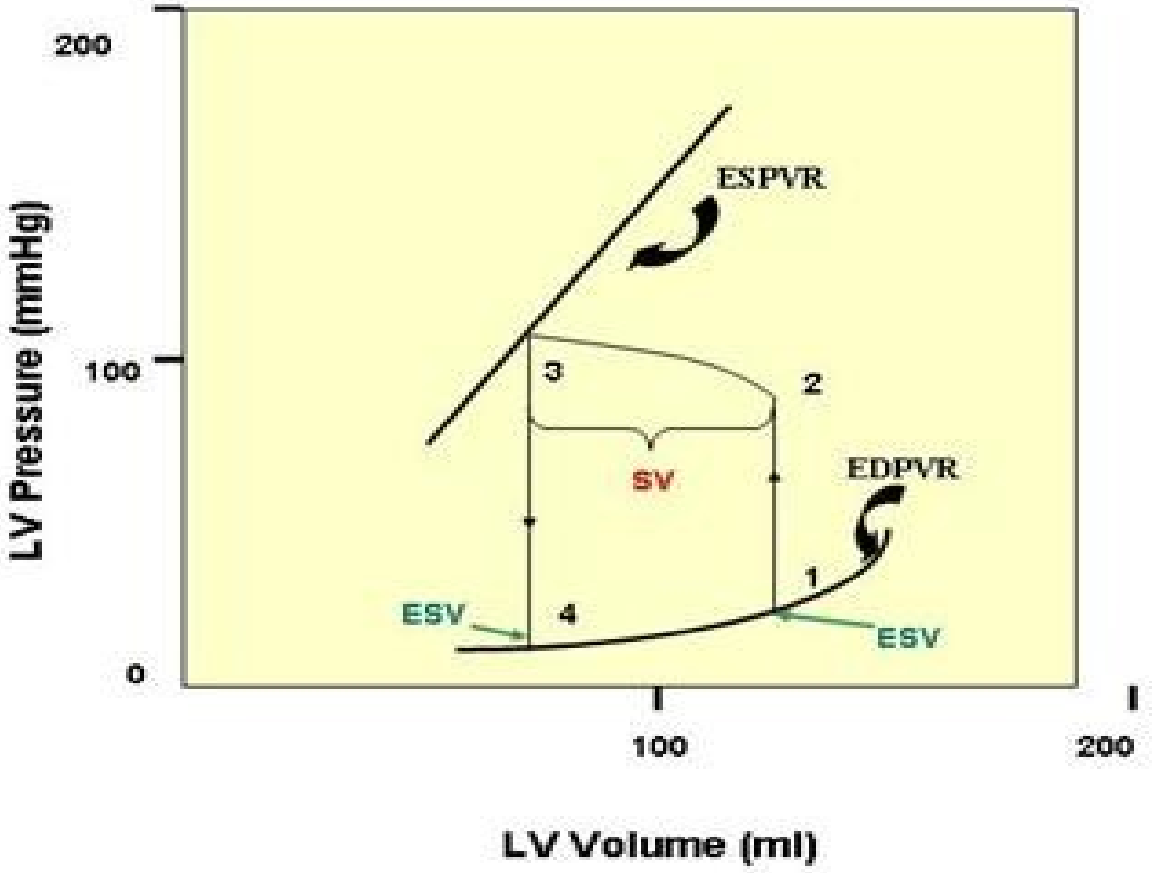
- External work(stroke work) is work done to eject blood under pressure. stroke work= SV×P
- Internal work is work done to change shape of heart for ejection. Wall stress directly proportional to internal work
- Both internal work and external work consume oxygen

- Wall motion abnormalities
- Valvular dysfunction

Methods to measure CO

- Fick principal
- Thermodilution
- Dye dilution
- Ultrasonography
- Thoracic bioimpedance

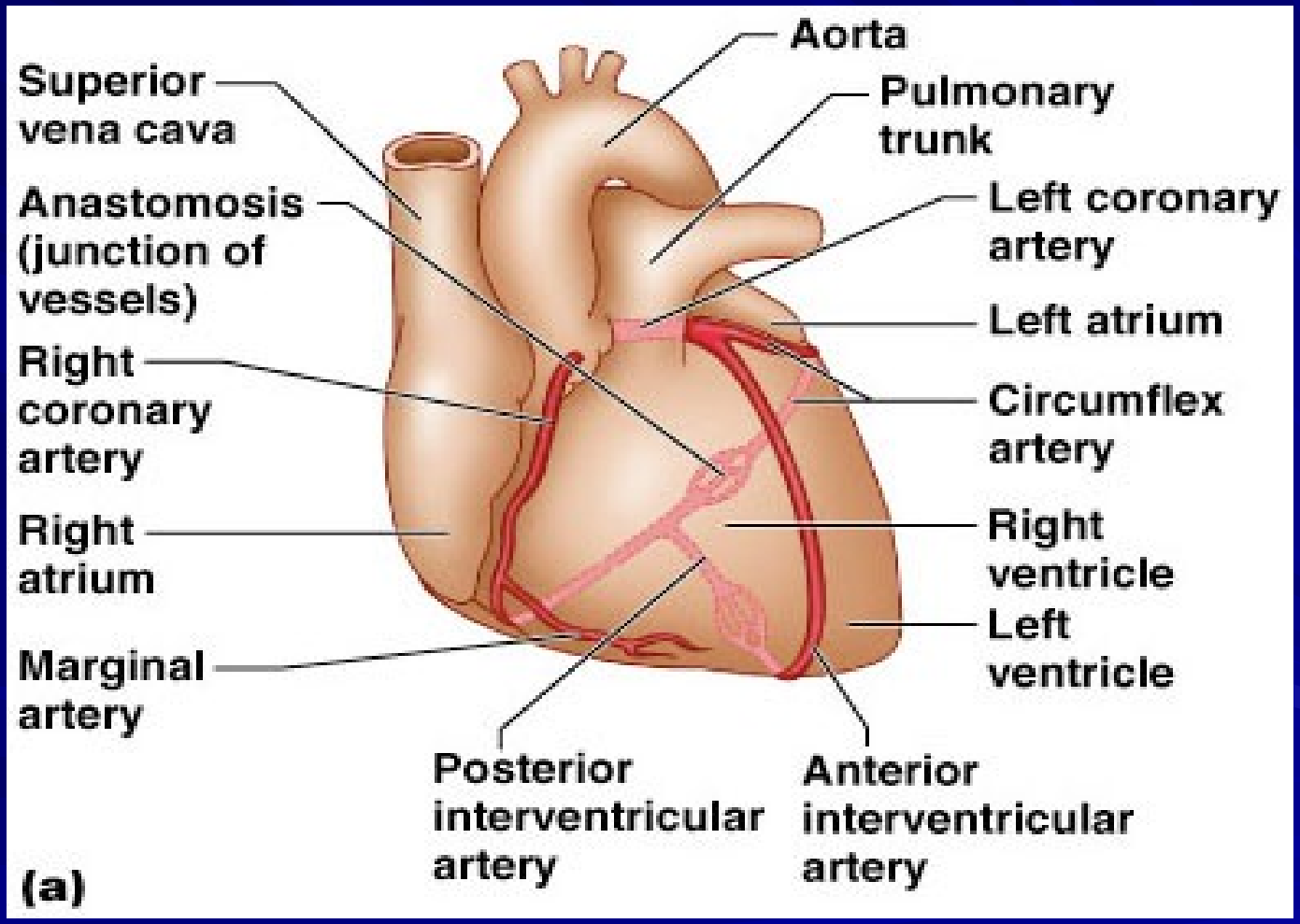
Pressure volume loop



Anatomy and physiology of coronary circulation

- Rt coronary artery
  - arises from anterior aortic sinus
  - supply RA, RV, inferior wall of LV, (60%) SA node, (80%) AV node
- Posterior descending artery
  - 80% branch of RCA (rt dominant circulation)
  - 20% branch of LCA (lt dominant circulation)
  - supplies interventricular septum and inferior wall

ARTERIAL SUPPLY

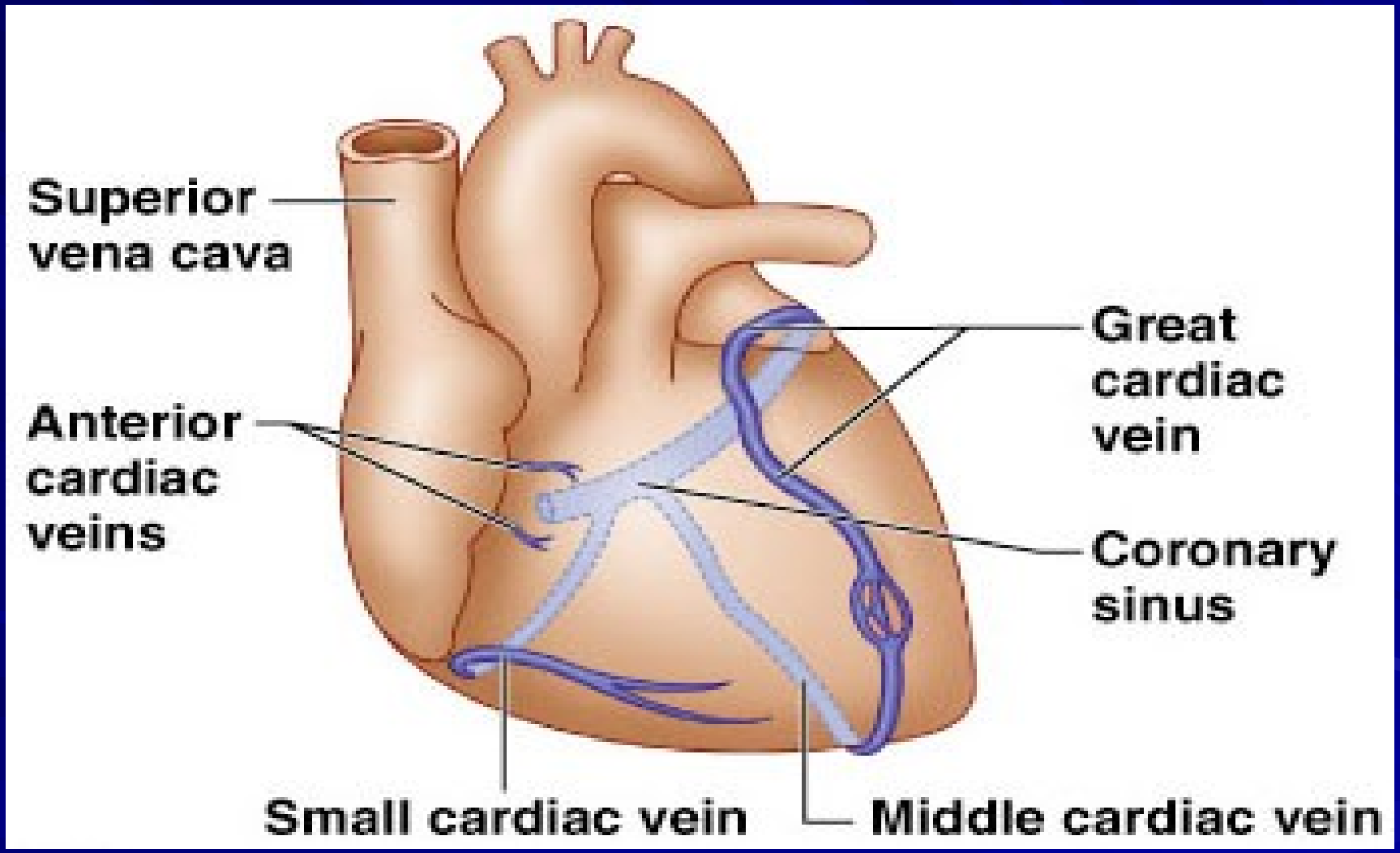


- Left coronary artery
  arises from posterior aortic sinus
  supply LA, LV, most of interventricular septum
- Left anterior descending
  septum and anterior wall
- Left circumflex
  lateral wall

Venous drianage

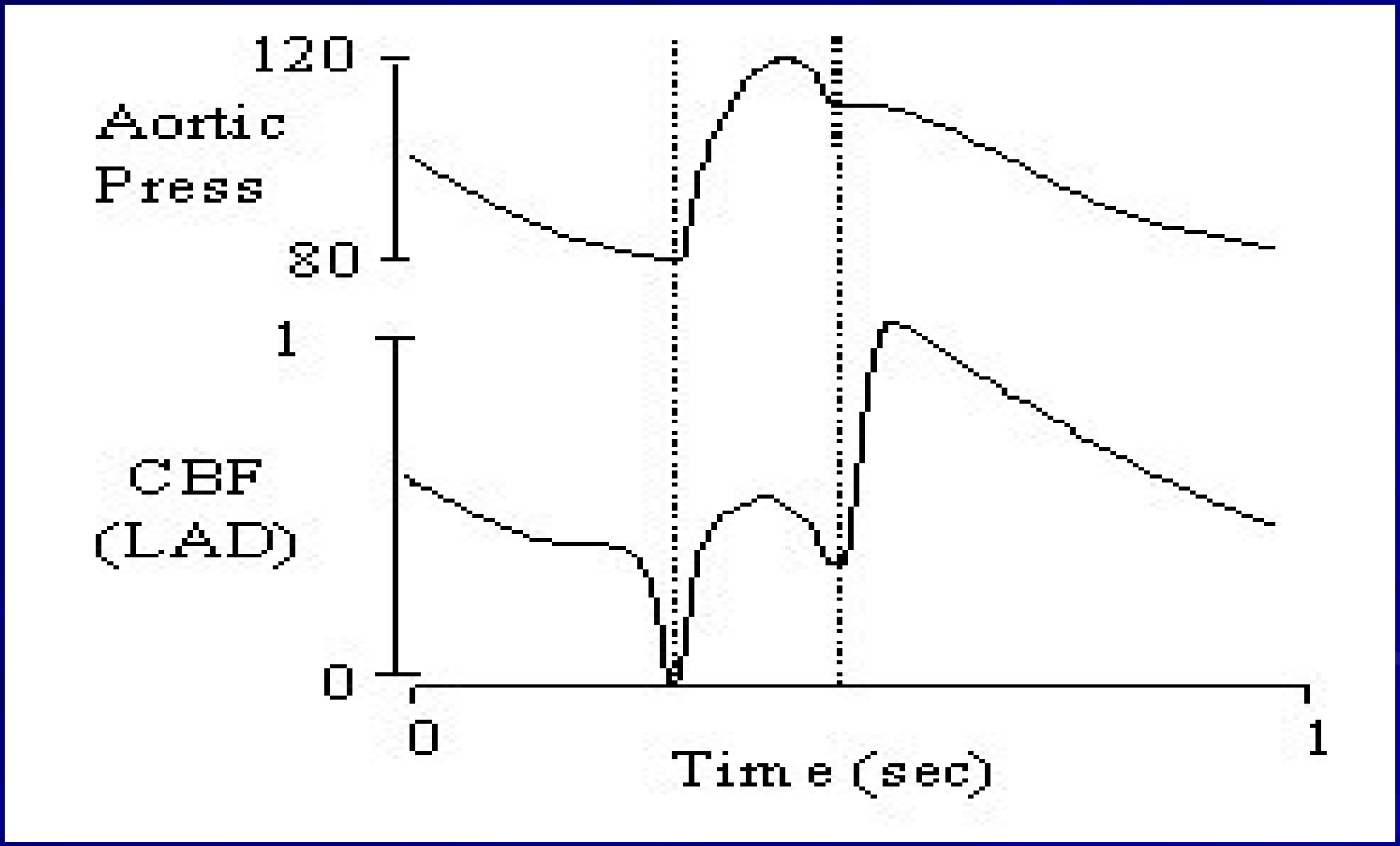
- Coronary sinus
  - great cardiac vein
  - middle cardiac vein
  - small cardiac vein
  - oblique vein
- Anterior cardiac vein
- Venae cordae minimae

VENOUS DRIANAGE



Determinants of coronary perfusion

- Coronary perfusion is intermittent compared to continous in other organs
- CPP = Aortic diastolic pressure – LVEDP
- LV is perfused entirely during diastole
- RV is perfused during both systole & diastole


120
Aortic
Press
80
1
CBF
(LAD)
0
0
1
Time (sec)

Autoregulation of coronary blood flow

- Coronary blood flow = 250 ml/min at rest
- Myocardium regulates its blood supply between 50 to 170 mmhg
- Metabolic control
- Neurohumoral control

Neurohumoral control

When blood pressure decreases

↓

Blood flow decreases

↓

Vascular smooth muscle relaxation

↓

Blood flow increases

Metabolic control

When blood flow decreases

↓

Metabolites accumulate

↓

Vasodilatation occurs

↓

Blood flow increases

Myocardial oxygen balance

- Myocardium extracts 65% 0_2 in arterial blood compared to 25% in most other tissues
- Cannot compensates for reduction in blood flow by extracting more 0_2 from Hb
- Any increase in demand must be met by an increase in coronary blood flow

Myocardial 0_2 supply & demand

- Supply
  - HR
  - coronary perfusion pressure
  - arterial 0_2 content
  - coronary vessel diameter

Myocardial 0_2 supply & demand

- Demand
  - basal requirement
  - HR
  - wall tension
  - contractility

Systemic circulation

- Arteries (wind kessel vessels)
- Arterioles (resistance vessels)
- Capillaries
- Veins (capacitance vessels)

Normal distribution of blood volume

- Heart 7%
- Pulmonary circulation 9%
- Systemic circulation
  - Arteries 15%
  - Capillaries 5%
  - Veins 64%

Autoregulation

- Defination

  Ability of organ to maintain constant blood flow over wide range of perfusion pressure
- Mechanism

  metabolic

  myogenic

Arterial blood pressure

- Mean arterial pressure

$$MAP = DP + PP/3$$

Control of arterial blood pressure

- Immediate control
- Intermediate control
- Long term control

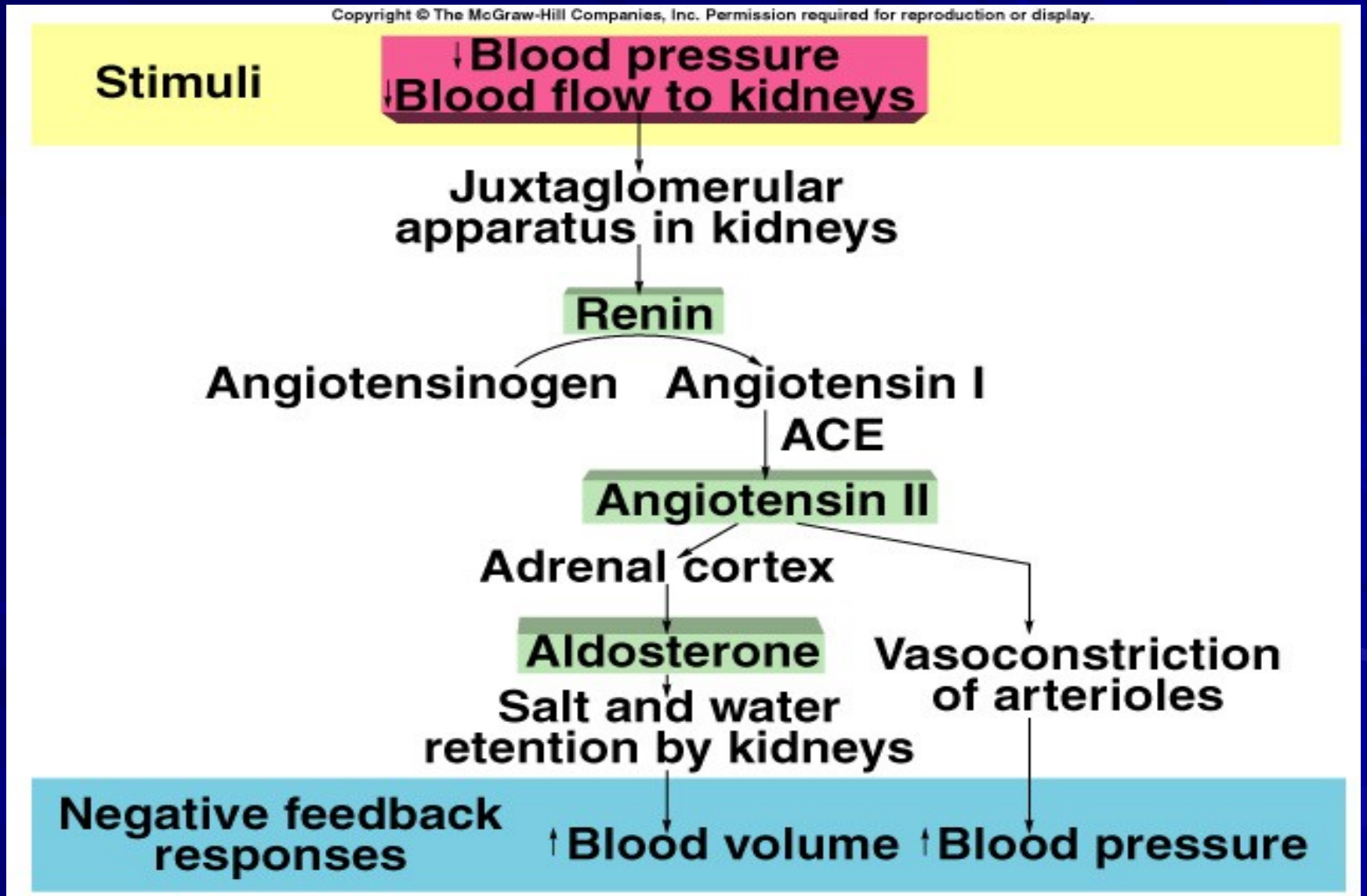
Immediate control

- Minute to minute control of BP
- central sensors
- Peripheral baroreceptor(stretch receptors)
  - aortic
  - carotid
- Chemoreceptor

Intermediate control

- After few minutes of sustained decrease in BP
- Renin angiotensin aldosteron system
- ANP
- Altered capillary permiability

Renin angiotensin aldosterone system



Atrial Natriuretic Peptide

- Produced by the atria of the heart.
- Stretch of atria stimulates production of ANP.
  - Antagonistic to aldosterone and angiotensin II.
  - Promotes Na^+ and H_20 excretion in the urine by the kidney.
  - Promotes vasodilation.

Long term control

- After hours of sustained change in BP
- Sodium and water retension

Cardiac reflexes

- Baroreceptor reflex
- Chemoreceptor reflex
- Bainbridge reflex
- Bezold jarish reflex
- Valsalva maneuver
- Cushings reflex
- Occulocardiac reflex

Baroreceptor reflex

↑ BP

⇓

↑ BR in carotid sinus & aortic arch

⇓

Sinus nerve & Aortic nerve

⇓

IX & X nerve

⇓

N. solitarius

⇓

↑ vagal tone

⇓

↓ HR

Chemoreceptor reflex

↓pO_2 ↑ pCO_2 & ↓pH

⇓

↑ CR in carotid body & aortic arch

⇓

Sinus nerve & Aortic nerve

⇓

IX & X nerve

⇓

↑ Respiratory centre

⇓

↑ ventilatory drive

Bainbridge reflex

Venous engorgement of atria & great veins

⇓

Stimulation of stretch receptors

⇓

X nerve

⇓

CVS center medulla

⇓

↓ Vagal tone

⇓

↑ HR

Bezold jarish reflex

Ischemia

⇓

Receptors in LV

⇓

X nerve

⇓

Reflex bradycardia, Hypotension & coronary artery dilation

Valsalva maneuver

- Forced expiration against closed glottis

  ↑ Intrathoracic pressure → ↑CVP → ↓ V.R → ↓ CO &BP → sensed by BR → ↑ HR & contractility

- When glottis opens

  ↑ VR → ↑ contractility → ↑ BP →sensed by BR → ↓ HR & BP

Cushings reflex

↑ Intracranial pressure

⇓

Cerebral ischemia

⇓

↑ VMC

⇓

↑SNS - ↑BP

⇓

↑BR

⇓

↑CIC

⇓

↑Vagal tone

⇓

reflex bradycardia ↓ HR

Occulocardiac reflex

Pressure on eye

⇓

long & short ciliary nvs

⇓

ciliary ganglion

⇓

gasserion ganglia

⇓

↑ PNS → BRADYCARDIA

Thank you

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