1. Introduction to Cardiovascular Pathophysiology

Introduction to Cardiovascular Pathophysiology

Munther K. Homoud, MD
Tufts-New England Medical Center
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2. Coronary Anatomy

Coronary Anatomy

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3. Actin-Myosin Structure

Actin-Myosin Structure

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4. The Sarcomere’s Contractile Proteins

The Sarcomere’s Contractile Proteins

- Myosin is the “thick” filament consisting of 300 longitudinally arranged molecules
- Myosin “heads” connect with the actin molecules in the process of contracting and contains ATPase
- Actin is the “thin filament”
- Tropomyosin lies within actin inhibiting contraction
- Troponin regulates the interaction between actin and myosin
5. Excitation-Contraction Coupling

Excitation-Contraction Coupling

- \( \text{Ca}^{++} \) entering the cell during Phase 2 of the MAP triggers the release of \( \text{Ca}^{++} \) from the sarcoplasmic reticulum
- \( \text{Ca}^{++} \) binds to TP-C1, inhibiting TP-I allowing the myosin head to bind to actin (coupling)
- \( \text{Ca}^{++} \) is actively pumped out of the SR
- At the end of Phase 2 uncoupling (relaxation) begins to occur when the concentration of \( \text{Ca}^{++} \) falls

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6. Excitation-Contraction Coupling

Excitation-Contraction Coupling

- Myocardial contraction is the result of reversible binding of myosin to actin through troponin
- The process is dependent on \( \text{Ca}^{++} \)
- Relaxation is an active process where uncoupling of myosin from actin begins with the reduction in intracellular \( \text{Ca}^{++} \)

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7. The Cardiac Electrical System

The Cardiac Electrical System

- Impulse is generated in the SA node
- Impulse is conducted to the ventricle across the AV node
- The impulse is then carried down specialized conduction fibers through the bundle of His to the right and left bundle branches to the ventricles.
- The ventricular cardiomyocytes are activated via the specialized Purkinje fibers

8. The Cardiac Cycle

The Cardiac Cycle

- Aortic Valve Opens
- Aortic Valve Closes
- Mitral Valve Opens
- Mitral Valve Closes
- Diastole
- Systole
- LA Pressure
- LV Pressure

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9. **Heart Sounds**

![Heart Sounds Diagram]

10. **The Cardiac Cycle**

![The Cardiac Cycle Diagram]
Components of Diastole

12. Introduction to Cardiovascular Pathophysiology: Slide 12
13. Determinants of Cardiac Output

Determinants of Cardiac Output

1. Preload

2. Afterload

3. Contractility (Inotropy)

14. Determinants of Cardiac Output

Determinants of Cardiac Output

Preload

- In a normal heart, presystolic stretch is one of the determinants of contractility
- The Frank-Starling law states that the greater the preload, the greater cardiac output
- End-diastolic volume is reflected in end-diastolic pressure. LVEDP = LA pressure in the absence of mitral disease
- Pulmonary artery capillary wedge pressure (PCWP) = LA pressure = PA diastolic pressure (in the absence of pulmonary vascular disease)
Determinants of Cardiac Output

Contractility

- Cardiac property that determines strength of contraction independent of preload or afterload.

*Compare the difference in stroke volume at a fixed preload when contractility changes*

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Determinants of Cardiac Output

Relationship between *preload* (pulmonary capillary wedge pressure PCWP) cardiac output and stroke work in a heart with Normal contractility, Enhanced contractility and Depressed contractility

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17. Determinants of Cardiac Output Contractility

Determinants of Cardiac Output Contractility

Left Ventricular Ejection Fraction (LVEF)

\[
\text{LVEF} = \frac{\text{STROKE VOLUME}}{\text{END DIASTOLIC VOLUME}}
\]

18. Left Ventricular Ejection Fraction

Left Ventricular Ejection Fraction

\[
\text{LVEF} = \frac{\text{STROKE VOLUME} - \text{END DIASTOLIC VOLUME} - \text{END SYSTOLIC VOLUME}}{\text{END DIASTOLIC VOLUME}}
\]

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Determinants of Cardiac Output

Afterload

- Is the pressure the left ventricle needs to overcome during systole
- Defined as Wall Stress during systole
- Laplace’s formula:
  \[ \text{Wall Stress} = \frac{P \times r}{t} \]
- Systolic pressure is often used to represent afterload

The Pressure-Volume Loop

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21. The Pressure-Volume Loop Decline in Inotropy

The Pressure-Volume Loop Decline in Inotropy

The slope $E^*$ represents an inotropic state lower than $E_1$. The width of the area bounded by the Pressure-Volume loop represents cardiac output. One can see that the width of the area $abcd$ is greater than the width of $abc^*d^*$. The lower cardiac output is expected if preload and afterload remain fixed.

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22. The Pressure-Volume Loop Increase in Afterload

The Pressure-Volume Loop Increase in Afterload

At a fixed preload and inotropic state an increase in afterload such as an increase in blood pressure changes the pressure-volume loop. This may result in a smaller area $abc^*d^*$ than the baseline area $abcd$ representing a decline in cardiac output.

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23. The Pressure-Volume Loop Decrease in Preload

The Pressure-Volume Loop Decrease in Preload

At a fixed afterload and inotropic state a decrease in preload such as after hemorrhage or dehydration results in a lower cardiac output. The decrease in preload is represented by $a^*$ which represents a lower preload volume than $a$. On the pressure-volume loop the width of the area with a lower preload, $a^*b^*cd$ is smaller than the baseline loop $abcd$.

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24. Pressure Volume Loop

Pressure Volume Loop

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25. Flow Volume Loops (The Cardiac Cycle)

Flow Volume Loops
(The Cardiac Cycle)

End of systole, the end systolic pressure-volume relationship (slope) reflects degree of inotropy

LV pressure exceeds aortic pressure the AV opens and systole commences

Isovolumic relaxation

Beginning of diastole, MV Opens and LV filling commences

LV filling ends, the receptors are stretched, systole commences

26. Flow Volume Loops (The Cardiac Cycle)

Flow Volume Loops
(The Cardiac Cycle)

The determinants of cardiac output (the width of the loop) are
1. Inotropy
2. Preload
3. Afterload

A shift of the ESPVR to the left indicates increased inotropy. Note the increase in the width of the loop


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27. Intra Cardiac Diastolic Pressures

In diastole, the tricuspid and mitral valves are open. The RA and RV, The LA and LV are open to each other and their pressures are equal.

RA = RVd
LA = LVd

In the absence of pulmonary vascular disease, PA diastolic pressure = PCWP (pulmonary capillary wedge pressure) = LA = LV ed diastolic pressure (LVEDP) this represents Left ventricular loading (preload)

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28. Normal Intracardiac Pressures

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29. Hemodynamic Measurement

30. Determinants of Blood Pressure

Determinants of Blood Pressure

Blood Pressure

Cardiac Output

Peripheral Vascular resistance

Heart Rate

Stroke Volume

Preload

Contractility

Afterload
31. Hypovolemic Shock (Hemorrhage, Dehydration)

Hypovolemic Shock
(Hemorrhage, Dehydration)

Blood Pressure

Cardiac Output
Stoke Volume

Heart Rate
Preload
Contractility
Afterload

Peripheral Vascular resistance

32. Cardiogenic Shock (Post Extensive Myocardial Infarction)

Cardiogenic Shock
(Post Extensive Myocardial Infarction)

Blood Pressure

Cardiac Output
Stoke Volume

Heart Rate
Preload
Contractility
Afterload

Peripheral Vascular resistance

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33. Hypotension Secondary to Slow Heart Rate

Hypotension Secondary to Slow Heart Rate

Blood Pressure

Cardiac Output

Heart Rate

Stroke Volume

Preload

Contractility

Afterload

Peripheral Vascular resistance

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34. Hypotension Secondary to Anaphylactic Shock or Sepsis

Hypotension Secondary to Anaphylactic Shock or Sepsis

Blood Pressure

Cardiac Output

Heart Rate

Stroke Volume

Preload

Contractility

Afterload

Peripheral Vascular resistance

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35. Measuring Vascular Resistance

Measuring Vascular Resistance

- Resistance = Pressure Gradient/Cardiac Output (CO)
- Pulmonary Vascular Resistance = (Mean PA pressure - LA pressure)/CO
- Systemic Vascular Resistance = (Mean Aortic pressure - RA pressure)/CO
- Mean Pulmonary pressure = (Systolic pressure + 2 Diastolic pressure)/3
- Mean Arterial pressure = (Systolic pressure + 2 Diastolic pressure)/3

36. The Monophasic Action Potential (MAP)

The Monophasic Action Potential (MAP)

Ca

Na → ↓ → K

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37. Monophasic Action Potential (Cardiac Muscle Cell)

Monophasic Action Potential
(Cardiac Muscle Cell)

+ 10 mV

Phase 1

Phase 2

Phase 0
Depolarization
Na⁺ Enters

- 90 mV

QRS

T

Phase 3
Repolarization
K⁺ is extruded

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38. Monophasic Action Potential (Effect of Potassium Channel Blo...
39. Effect of Potassium Channel Blockage

**Effect of Potassium Channel Blockage**

![Graph showing the effect of potassium channel blockage on the action potential of a cardiac muscle cell.](image)

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40. Monophasic Action Potential (Cardiac Muscle Cell)

**Monophasic Action Potential (Cardiac Muscle Cell)**

![Graph showing the monophasic action potential of a cardiac muscle cell.](image)

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41. Monophasic Action Potential (Cardiac Pacemaker Cell)

Monophasic Action Potential  
(Cardiac Pacemaker Cell)

\[ +10 \text{ mV} \]

Phase 0  
\( \text{Ca}^{++} \) influx

Phase 3  
\( \text{K}^{+} \) efflux

Phase 4  
\( \text{Na}^{+} \) influx via \( I_f \)

\(-60 \text{ mV}\)

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42. Monophasic Action Potential (Cardiac Pacemaker Cell)

Monophasic Action Potential  
(Cardiac Pacemaker Cell)

\[ +10 \text{ mV} \]

Phase 4  
Threshold Potential

Resting Potential

\(-40 \text{ mV}\)
\(-60 \text{ mV}\)

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43. The Monophasic Action Potential

The Monophasic Action Potential

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44. Conduction of Cardiac Impulse

Conduction of Cardiac Impulse

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45. The Cardiac Cycle

The Cardiac Cycle

120 mmHg

80 mmHg

10 mmHg

Electrocardiogram

P
QRS
T

Monophasic Action Potential

45

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