Heart Part 2

Cardiac Muscle Contraction

• Heart muscle:
  – Is stimulated by nerves and is self-excitable (automaticity)
  – Contracts as a unit
  – Has a long (250 ms) absolute refractory period
• Cardiac muscle contraction is similar to skeletal muscle contraction

Heart Physiology: Intrinsic Conduction System

• Autorhythmic cells:
  – Initiate action potentials
  – Have unstable resting potentials called pacemaker potentials
  – Use calcium influx (rather than sodium) for rising phase of the action potential

Pacemaker and Action Potentials of the Heart

Heart Physiology: Sequence of Excitation

• Sinoatrial (SA) node generates impulses about 75 times/minute
• Atrioventricular (AV) node delays the impulse approximately 0.1 second
• Impulse passes from atria to ventricles via the atrioventricular bundle (bundle of His)

Heart Physiology: Sequence of Excitation

• AV bundle splits into two pathways in the interventricular septum (bundle branches)
  – Bundle branches carry the impulse toward the apex of the heart
  – Purkinje fibers carry the impulse to the heart apex and ventricular walls
Heart Physiology: Sequence of Excitation

Heart Excitation Related to ECG

Extrinsic Innervation of the Heart

- Heart is stimulated by the sympathetic cardioacceleratory center
- Heart is inhibited by the parasympathetic cardioinhibitory center

Electrocardiography

- Electrical activity is recorded by electrocardiogram (ECG)
- P wave corresponds to depolarization of SA node
- QRS complex corresponds to ventricular depolarization
- T wave corresponds to ventricular repolarization
- Atrial repolarization record is masked by the larger QRS complex

Heart Sounds

- Heart sounds (lub-dup) are associated with closing of heart valves
  - First sound occurs as AV valves close and signifies beginning of systole
  - Second sound occurs when SL valves close at the beginning of ventricular diastole
Cardiac Cycle

- Cardiac cycle refers to all events associated with blood flow through the heart
  - Systole – contraction of heart muscle
  - Diastole – relaxation of heart muscle

Phases of the Cardiac Cycle

- Ventricular filling – mid-to-late diastole
  - Heart blood pressure is low as blood enters atria and flows into ventricles
  - AV valves are open, then atrial systole occurs

Phases of the Cardiac Cycle

- Ventricular systole
  - Atria relax
  - Rising ventricular pressure results in closing of AV valves
  - Isovolumetric contraction phase
  - Ventricular ejection phase opens semilunar valves

Phases of the Cardiac Cycle

- Isovolumetric relaxation – early diastole
  - Ventricles relax
  - Backflow of blood in aorta and pulmonary trunk closes semilunar valves
- Dicrotic notch – brief rise in aortic pressure caused by backflow of blood rebounding off semilunar valves

Phases of the Cardiac Cycle

Cardiac Output (CO) and Reserve

- CO is the amount of blood pumped by each ventricle in one minute
- CO is the product of heart rate (HR) and stroke volume (SV)
- HR is the number of heart beats per minute
- SV is the amount of blood pumped out by a ventricle with each beat
- Cardiac reserve is the difference between resting and maximal CO
Cardiac Output: Example

• CO (ml/min) = HR (75 beats/min) x SV (70 ml/beat)
• CO = 5250 ml/min (5.25 L/min)

Regulation of Stroke Volume

• SV = end diastolic volume (EDV) minus end systolic volume (ESV)
• EDV = amount of blood collected in a ventricle during diastole
• ESV = amount of blood remaining in a ventricle after contraction

Factors Affecting Stroke Volume

• Preload – amount ventricles are stretched by contained blood
• Contractility – cardiac cell contractile force due to factors other than EDV
• Afterload – back pressure exerted by blood in the large arteries leaving the heart

Frank-Starling Law of the Heart

• Preload, or degree of stretch, of cardiac muscle cells before they contract is the critical factor controlling stroke volume
• Slow heartbeat and exercise increase venous return to the heart, increasing SV
• Blood loss and extremely rapid heartbeat decrease SV

Preload and Afterload

Extrinsic Factors Influencing Stroke Volume

• Contractility is the increase in contractile strength, independent of stretch and EDV
• Increase in contractility comes from:
  – Increased sympathetic stimuli
  – Certain hormones
  – Ca²⁺ and some drugs
Extrinsic Factors Influencing Stroke Volume

- Agents/factors that decrease contractility include:
  - Acidosis
  - Increased extracellular $K^+$
  - Calcium channel blockers

Contractility and Norepinephrine

- Sympathetic stimulation releases norepinephrine and initiates a cyclic AMP second-messenger system

Regulation of Heart Rate

- Positive chronotropic factors increase heart rate
- Negative chronotropic factors decrease heart rate

Regulation of Heart Rate: Autonomic Nervous System

- Sympathetic nervous system (SNS) stimulation is activated by stress, anxiety, excitement, or exercise
- Parasympathetic nervous system (PNS) stimulation is mediated by acetylcholine and opposes the SNS
- PNS dominates the autonomic stimulation, slowing heart rate and causing vagal tone

Atrial (Bainbridge) Reflex

- Atrial (Bainbridge) reflex – a sympathetic reflex initiated by increased blood in the atria
  - Causes stimulation of the SA node
  - Stimulates baroreceptors in the atria, causing increased SNS stimulation

Chemical Regulation of the Heart

- The hormones epinephrine and thyroxine increase heart rate
- Intra- and extracellular ion concentrations must be maintained for normal heart function
Factors Involved in Regulation of Cardiac Output

- Exercise
- Physical or emotional stress
- Increased heart rate
- Increased blood volume
- Increased blood pressure
- Atrial fibrillation
- Pulmonary hypertension
- Coronary atherosclerosis
- Pulmonary edema
- Hypertension
- Low cardiac output

Congestive Heart Failure (CHF)

- Congestive heart failure (CHF) is caused by:
  - Coronary atherosclerosis
  - Persistent high blood pressure
  - Multiple myocardial infarcts
  - Dilated cardiomyopathy (DCM)

Developmental Aspects of the Heart

- Embryonic heart chambers:
  - Sinus venous
  - Atrium
  - Ventricle
  - Bulbus cordis

Developmental Aspects of the Heart

- Fetal heart structures that bypass pulmonary circulation:
  - Foramen ovale connects the two atria
  - Ductus arteriosus connects pulmonary trunk and the aorta

Examples of Congenital Heart Defects

- Ventricular septal defect: Occurs in about 1 in every 1,000 births
- Patent ductus arteriosus: Occurs in about 1 in every 1,000 births
- Pulmonary stenosis: Occurs in about 1 in every 1,000 births
Age-Related Changes Affecting the Heart

- Sclerosis and thickening of valve flaps
- Decline in cardiac reserve
- Fibrosis of cardiac muscle
- Atherosclerosis