Circulatory System and Disorders

Course 2

Heartbeat Coordination

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Introduction

- The human heart has a **special system** for rhythmic self-excitation and repetitive contraction (100.000/day).
  - Generates rhythmical electrical impulses to initiate rhythmical contraction of the heart muscle
  - Conducts these impulses rapidly through the heart.
- When this system functions normally,
  - the atria contract about one sixth of a second ahead of ventricular contraction,
  - allows all portions of the ventricles to contract almost simultaneously
- This system is called **«Specialized Excitatory and Conductive System of the Heart»** or **«Cardiac Conduction System»** in short.

The Cardiac Conduction System

- Excitation of the heart normally occurs in an ordered manner:
  1. SA node (**primary pacemaker**)
  2. spread of action potentials throughout the atria.
  3. AV node (conduction is slowed)
  4. Bundle of His (atrioventricular passage) (A-V bundle)
  5. Purkinje system

- The specialized conductive fibers are **muscle** fibers but they contract only feebly because they contain few contractile fibrils.

Sinus (Sinoatrial) Node (SA Node)

- SA node is the primary pacemaker of the heart.
  - 8 mm length, 2 mm thickness,
  - lies posteriorly in the groove at the junction between the superior vena cava and the right atrium.
- The fibers of this node have almost no contractile muscle filament.
- Sinus nodal fibers connect directly with the atrial muscle fibers so that any action potential that begins in the sinus node spreads immediately into the atrial muscle wall.

Sinus (Sinoatrial) Node (SA Node)

- The SA node contains two principal cell types:
  1. Small, round cells that have few organelles and myofibrils
  2. Slender, elongated cells
- The round cells are the pacemaker cells;
- The slender, elongated cells conduct the impulses within the node and to the nodal margins.

Overdrive Supression

- The automaticity of pacemaker cells diminishes after these cells have been excited at a high frequency. This phenomenon is known as **overdrive suppression.**

- Because the intrinsic rhythmicity of the SA node is greater than that of the other latent pacemaking sites in the heart, firing of the SA node tends to suppress the automaticity in other loci.

Ectopic Pacemakers

- Regions of the heart other than the SA node may initiate beats in special circumstances, are called ***ectopic foci*** or ***ectopic pacemakers***.

- Ectopic foci may become pacemaker when
  1. Their own rhythmicity becomes enhanced
  2. Rhythmicity of higher order pacemakers becomes depressed
  3. All conduction pathways between the ectopic focus and regions with great rhythmicity become blocked

- They may act a safety mechanism when primary pacemaking centers fail. However they may also induce rhythm disturbances.

Altered Sinoatrial Rhythms

- Changes in the firing rate of the SA node are usually produced by cardiac autonomic nerves.

- When the firing rate of the SA node
  - is decreased, the heart rate also decreases **(bradycardia)**.
  - is increased, the heart rate also increases **(tachycardia)**.

Ionic Basis of Automaticity

- A pacemaker cell is characterized by slow depolarization throughout Phase 4.

- Several ionic currents contributes to the slow depolarization
  1. Decrease of outward i_K current (lacks i_{K1})
  2. A hyperpolarizaytion induced inward Na^+ current **«i_f»: funny current**
  3. Inward Ca^{++} current (T-type Ca^{++} channels)

Ionic Basis of Automaticity

- Phase 0;
  - Nodal cell lacks fast i_{Na+} channels.
  - L-Type Ca^{2+} channels are responsible of upstroke
- Phase 3
  - i_K channels completes the repolarization

Modulation of SA Node

- Normal rhythm of the heart occurs because of spontaneous pacemaker activity (automaticity) of SA node.

- The two most important outside influence of SA node come from autonomic nervous system.
  - Sympathetic
  - Parasympathetic

Modulation of SA Node

- Parasympathetic System (via muscarinic receptors):
  - Activation of specific potassium channels: the acetylcholine-regulated potassium channels (K_{ACh}).
  - ACh also depresses the i_f and i_{Ca} currents.

  Result: (1) Hyperpolarization **(2)** Prepotential slope is decreased

  = (-) chronotropic effect

- Sympathetic System (via adrenergic receptors):
  - Augmentation of i_f and i_{Ca}

  Result: Prepotential slope is increased

  = (+) chronotropic effect

(A) A reduction in the of slow diastolic depolarization diminishes the firing frequency.

(B) An increase in the threshold potential (from TP-1 to TP-2) diminishes the firing frequency.

Atrial Conduction

1. From the SA node, the cardiac impulse spreads radially throughout the right atrium (≈1m/sec).

2. A special pathway, the anterior interatrial myocardial band (or **Bachmann's bundle**), conducts the SA node impulse directly to the left atrium.

3. The wave of excitation proceeds inferiorly through the right atrium and ultimately reaches the AV node

Atrioventricular Node (AV Node)

- In adult humans, this node is approximately 15 mm long, 10 mm wide, and 3 mm thick.
- The node is situated posteriorly on the right side of the interatrial septum near the ostium of the coronary sinus.
- AV node is organized so that the cardiac impulse does not travel from the atria into the ventricles too rapidly.
- This delay allows time for the atria to empty their blood into the ventricles before ventricular contraction begins.

SA node

↓

Internodal pathways

↓

AV node

↓

Ventricle

Atrioventricular Node (AV Node)

- The AV node contains the same two cell types as the SA node, but the round cells in the AV node are less abundant and the elongated cells predominate.

- The AV node is made up of three functional regions:
  1. The atrionodal **(AN)** region, or the transitional zone between the atrium and the remainder of the node;
  2. The nodal **(N)** region, or the midportion of the AV node;
  3. The nodal-His **(NH)** region, or the zone in which nodal fibers gradually merge with the **bundle of His.**

- The principal delay in conduction of impulses from the atria to the ventricles occurs in the **AN** and **N** regions of the AV node.

Atrioventricular Node (AV Node)

- A special characteristic of the A-V bundle is the inability, except in abnormal states, of action potentials to travel backward from the ventricles to the atria.
- This characteristic prevents re-entry of cardiac impulses by this route from the ventricles to the atria, allowing only forward conduction from the atria to the ventricles.
- Parasympathetic system slows the conduction rate of AV node = **(-) dromotropic effect**
- Sympathetic system enhances the conduction rate of AV node = **(+) dromotropic effect**

AV Conduction Blocks

- Abnormal prolongation of the AV conduction time is called a ***first-degree AV block***.
- If the atria are depolarized at a high repetition rate, only a fraction (e.g., half) of the atrial impulses might be conducted through the AV junction to the ventricles.
  It is called a ***second-degree AV block***.
- The conduction pattern in which none of the atrial impulses reaches the ventricles is called a ***third degree***, or ***complete AV block***.

Ventricular Conduction

- ***The bundle of His*** passes subendocardially down the right side of the interventricular septum for approximately 1 cm.
- Then divides into the **right** and **left bundle branches**.
- The right and the left bundle branch ultimately subdivide into a complex network of conducting fibers, called ***Purkinje system***

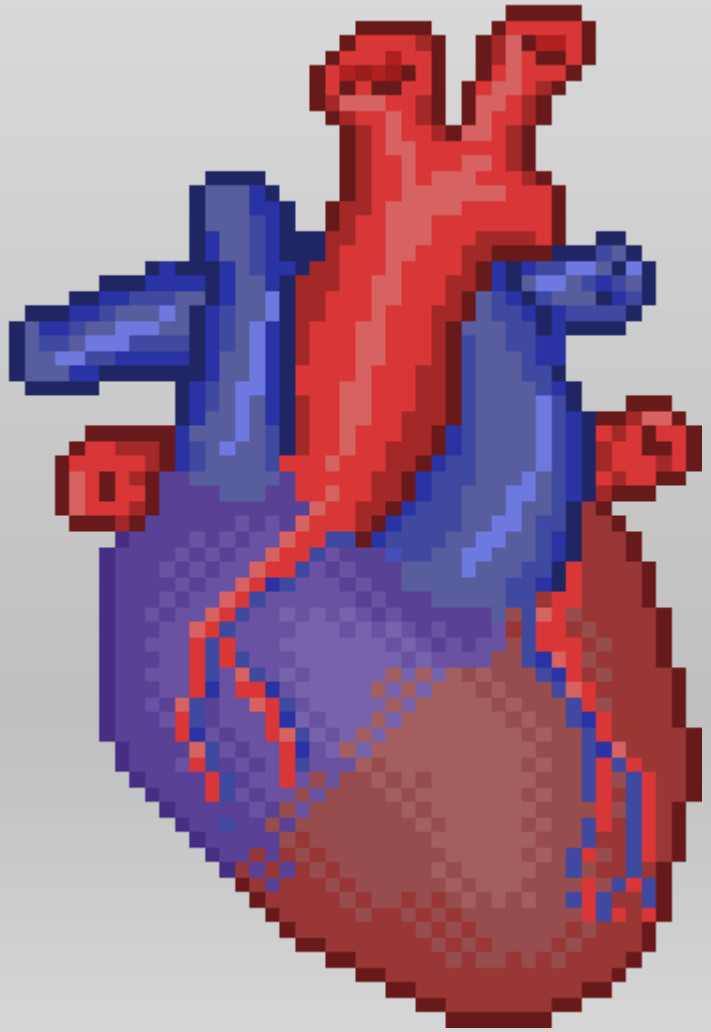
Purkinje Fibers

- Fast conduction (1 to 4 m/second) (Faster than in any other fiber type within the heart):
  1. Purkinje fibers have fast response action potential.
  2. Large diameter (70 to 80 µm) of the Purkinje fibers, (10 to 15µm in a regular mycoyte)
  3. Gap junction permeability is higher

Purkinje System

Spread of Cardiac Excitation in Ventricles

- Ventricular muscle depolarize and repolarize in a specific order:
  - Depolarization wave starts at the left side of the intraventricular septum.
  - Moves first to the right across the mid portion of the septum **(left → right)**.
  - Spreads **down** to the septum to the apex of the heart **(basis → apex)**.
  - Returns along ventricular walls **(apex → basis)**.
  - Proceeds form endocardium to epicardium **(inside → outside)**



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Thank you for your patience!