Overview of Human Anatomy and Physiology: Cardiac Conduction Pathway

Introduction

Welcome to the Overview of Human Anatomy and Physiology course on the Cardiac System. This module, the Cardiac Conduction Pathway, describes the cells and the electrical activity of the heart.

After completing this module, you should be able to:
1. Describe the types of cardiac muscle cells.
2. Identify the parts of the cardiac conduction pathway and their functions.
3. Discuss cardiac conduction and its relationship to an electrocardiogram (ECG).

Cardiac Muscle

Overview

The ability of the heart to maintain sufficient circulation depends on its ability to pump rhythmically and automatically. With each beat, contractions must be coordinated to ensure that blood continually flows in the correct direction at the correct time. How does cardiac muscle structure enable such coordinated contractions?

Structure

Cardiac muscle tissue accounts for the bulk of the myocardium and is composed of contractile units called sarcomeres. The myofibrils that make up sarcomeres appear striped, or striated, when examined microscopically. Cardiac muscle is also described as involuntary because it is not under conscious control.

Intercalated Discs

Intercalated discs, the intercellular junctions between the cardiac cells, facilitate rapid transmission of action potentials. Intercalated discs contain two types of junctions: desmosomes and gap junctions. Desmosomes attach the cells to one another, and gap junctions relay electrical signals between cells. What is the structure of these cardiac cells?

Cardiac Cell Types

Overview

Types of Cardiac Cells
There are two types of cardiac muscle cells: contractile cells and specialized cardiac cells that regulate contractile cells.

Contractile Cells

Contractile cells account for almost 99 percent of all muscle cells in the heart. Cardiac action potentials, which are electrical impulses, are transmitted between cells in the myocardium. These action potentials signal muscle fibers to shorten, resulting in muscular contraction, or systole. The
structure of intercalated discs and their junctions allows such efficient and rapid transmissions that action potentials generated in one part of the myocardium pass almost simultaneously throughout the entire heart, causing rapid contraction.

**Specialized Cardiac Cells**

Cardiac muscle also contains two types of specialized cells that do not contract but instead coordinate cardiac contractions. The nodal cells establish the rate of contractions, and the conducting cells transmit contractile stimuli to the myocardium. Let's take a closer look at these specialized cardiac cells.

**Nodal Cells**

Nodal cells can spontaneously generate cardiac action potentials at regular intervals. This characteristic is called self-excitability, or automaticity. Because nodal cells are coupled to all of the cardiac cell types, action potentials are transmitted to all conducting cells and muscle cells, resulting in a contraction.

**Pacemaker Cells**

However, not all nodal cells generate action potentials at the same rate. Pacemaker cells are the nodal cells that reach threshold for depolarization most quickly and establish the contraction rate of the heart. Pacemaker cells are located in the sinoatrial (SA) node and generate 70 to 80 action potentials per minute. Because this rate is faster than other components of the cardiac conduction system, the SA node sets the heart's contraction rate and is referred to as the pacemaker of the heart.

**Clinical Correlation: Artificial Pacemaker**

If the pacemaker cells of the heart are not working properly, the heart may beat irregularly. The heart rate may speed up or slow down erratically, or the atria and ventricles may beat independently in an uncoordinated fashion. These processes may lead to insufficient filling or contraction of the heart chambers and result in a dangerous drop in the amount of blood pumped by the heart to the rest of the body.

An artificial pacemaker can restore the normal rate and rhythm of the heart. This device, which is about the size of a half-dollar, consists of a battery, a pulse generator, and a lead that delivers the impulse of the pulse generator to the heart. The leads are placed in the heart and are connected to the rest of the pacemaker, which is implanted under the skin in the upper chest.

**Atrioventricular Node**

Another group of nodal cells that generates action potentials is located in the atrioventricular (AV) node. These cells are normally stimulated by the pace-setting action potentials of the SA node.

Now that we have examined the types of cardiac cells, let's investigate how they work together to produce heart contractions.

**Conducting System**

**Overview**

For the heart to maximize the force of its contraction, it must operate rhythmically. Specifically, atrial contraction must be followed by ventricular contraction so that both chambers can fill properly and pump blood effectively.

**Atrial Conducting System**
The SA node maintains the heart’s rhythmic pumping by setting the rate at which all cardiac muscle cells contract. The SA node is located in the wall of the right atrium and close to the point where the superior vena cava enters the heart.

Because cardiac cells are electrically coupled, impulses from the SA node spread rapidly through the walls of the atria, signaling them to contract. What occurs after atrial contraction?

After atrial contraction, signals travel to the AV node, which is located between the right atrium and right ventricle. Impulse transmission is delayed here for 0.1 seconds, which ensures that the atria have time to contract and empty into the ventricles.

**Conducting System Fibers**

After the delay, impulses are transmitted by the conduction fibers of the atroventricular bundle, which is also called the bundle of His. This bundle divides into two tracts, called bundle branches, that transmit impulses along the septum between the left and right ventricles.

**Ventricular Conducting System**

Impulses then continue through conduction myofibers, called Purkinje fibers, from the walls of the ventricles to the apex of the heart. The muscles of the ventricles are thus stimulated to contract from the bottom up, maximizing the force of their ejection.

How are the electrical currents of the cardiac conduction cycle measured?

**ECG**

**Overview**

*The Electrocardiogram*

The impulses that travel through the cardiac muscle produce electrical currents that are conducted through the body tissues to the body surface. These electrical currents can be detected by electrodes placed on the skin. A recording of these currents is an electrocardiogram, which is also referred to as an ECG or EKG. What are the components of an ECG?

**Recording Electrical Events**

An ECG noninvasively reveals much of the mechanical and electrical activity of the heart. The “waves” of an ECG tracing corresponding to one cardiac cycle are shown here.

First, the SA node generates a wave of electrical signals through both atria.

**P wave**

Then atrial contraction occurs, creating what is referred to as the P wave on the ECG.

**PR interval**

During the PR interval, the AV node slows impulse transmission, allowing the atria to empty into the ventricles before the ventricles contract. Bundle branches and Purkinje fibers conduct the signals to the apex of the heart and the ventricle walls.

**QRS complex**
During the QRS complex, powerful upward contractions from the apex trigger the ventricles to contract forcefully after the R wave peaks, and blood is forcefully ejected into the large arteries.

**T wave**

Ventricles then return to a resting state, which appears as the T wave.

**Complete Cardiac Cycle**

A complete cardiac cycle thus corresponds to an ECG tracing as shown here.

**Key Points**

- The main types of cardiac cells are contractile cells, nodal cells, and conducting cells. Contractile cells are responsible for the muscular contraction of the heart. Nodal cells establish the rate of contraction of the heart. Conducting cells transmit contractile stimuli to the myocardium.
- The cardiac conduction pathway consists of the SA node, the AV node, and the conduction fibers of the bundle of His and Purkinje fibers. The SA node sets the rate of the heart and causes the atrium to contract. Atrial contraction leads to stimulation of the AV node, which sends impulses through the bundle of His and Purkinje fibers, leading to ventricular contraction.
- An ECG records the electrical activity of the heart during the cardiac cycle. The P wave signals atrial contraction, the QRS complex signals ventricular contraction, and the T wave signals ventricular relaxation.