Cardiovascular Anatomy & Physiology

This course has been awarded 2.0 (two) contact hours

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RN.com acknowledges the valuable contributions of…

…Nadine Salmon, MSN, BSN, IBCLC, Clinical Content Manager for RN.com. She is a South African trained Registered Nurse, Midwife and International Board Certified Lactation Consultant. Nadine obtained an MSN at Grand Canyon University, with an emphasis on Nursing Leadership. Her clinical background is in Labor & Delivery and Postpartum nursing, and she has also worked in Medical Surgical Nursing and Home Health. Nadine has work experience in three countries, including the United States, the United Kingdom and South Africa. She worked for the international nurse division of American Mobile Healthcare, prior to joining the Education Team at RN.com. Nadine is the Lead Nurse

Planner for RN.com and is responsible for all clinical aspects of course development. She updates course content to current standards, and develops new course materials for RN.com.

… Lori Constantine MSN, RN, C-FNP, the original author of RN.com's Assessment Series: Cardiovascular Anatomy and Physiology.

Purpose & Objectives

The focus of this cardiovascular anatomy and physiology course is to teach nurses about the structures and functions of the cardiovascular system. The anatomical structures of the cardiovascular system work together to transport oxygenated blood and nutrients to the cells of the body and transport carbon dioxide and wastes from the cells to organs to eliminate waste.

Understanding the fundamental structures and functions of the cardiovascular system will allow you to provide care for all patients you encounter and intervene effectively for those with alterations in cardiovascular status.

After successful completion of this course, you will be able to:

Identify the functions of various anatomical structures within the cardiovascular system.

Discuss the functions of the cardiovascular system.

Discuss the physiology of how the cardiovascular system works.

Introduction

The human heart is one of the most amazing organs in the human body, which functions as a vital pump to deliver and retrieve blood for the entire body. Cardiovascular anatomy and physiology is an example of both a mechanical and an electrical organ system.

Although the heart is essentially a "pump," the complex anatomy and physiology that make it able to successfully keep a person alive is truly fascinating. Add to that the hormonal influences on the cardiovascular system and you have a truly complicated system of structures and events that need to operate correctly and efficiently to maintain homeostasis.

This course will examine the structure and function of the cardiovascular system. For an in-depth review of the assessment of cardiovascular function, please review the Cardiovascular Assessment Course.

Introduction

Before proceeding it is advisable to watch this brief animated video of the working heart to gain an overview of the anatomy and physiology of the heart, which will be discussed in greater detail throughout this presentation. (link to video: http://www.youtube.com/watch?v=NF68qhyfcoM)

Glossary

Aortic Valve: (Also known as a semilunar valve) is located between the left ventricle and the aorta.

Atrial Kick: When atrial contraction occurs, atrial blood is pushed down into the ventricles.

Atrioventricular Valves: (Also known as A-V valves) are located between the atria and ventricles on both the right and left sides of the heart.

Automaticity: Specialized cardiac cells can discharge an electrical current without an external pacemaker, or stimulus.

Autonomic Nervous System: Comprised of the sympathetic and parasympathetic nervous systems.

Baroreceptors: Are sensors located in the aortic arch, the carotid bodies of the external carotid arteries, the pulmonary artery and the atria, which respond to changes in blood pressure.

Bundle of His: (Also known as common bundle) is a collection of cardiac muscle fibers that connect the atria to the ventricles, and propogate atrial contraction rhythms to the ventricles.

Cardiac Output (C.O.): Is the amount of blood ejected by the left ventricle every minute. Cardiac output equals the stroke volume times the heart rate.

Chemoreceptors: Are sensors that detect abnormal changes in oxygen, carbon dioxide and hydrogen ion concentration in the blood stream.

Conductive Cells: Electrical cells that initiate electrical activity and conduct it through the heart.

Contracting Cells: Mechanical cells that respond to electrical impulses and contract to pump blood.

Coronary Sinus: Large vein that returns de-oxygenated blood to the right atrium.

Depolarized Cell: Is a positively charged cell in contraction.

Diastole: The resting phase of the cardiac cycle, when the ventricles are resting, or filling with blood (diastole).

Endocardium: The innermost layer of the heart.

Epicardium: Formed by the pericardium folding in on itself at the aorta to form an outer layer.

Heart Rate: Is the number of times (beats) per minute that the heart beats.

Mitral Valve: Located between the left atrium and left ventricle.

Myocardium: Forms the middle layer of the heart. Is the thickest layer and performs most of the work.

Pericardium: Outer protective layer of the heart.

Polarized Cell: Is a negatively charged cell at rest.

Pulmonic Valve: (Also known as a semilunar valve) is located between the pulmonary artery and the right ventricle.

Purkinje Fibers: A web of fibers that are found at the terminal ends of bundle branches and act to distribute electrical impulses to muscle cells.

Sinoatrial Node: A group of specialized cells located in the posterior wall of the right atrium.

Sinus of Valsalva: (Also known as aortic sinus) is a pouch of the aorta and pulmonary artery. When blood enters into the pouch, it closes the valves out at the beginning of diastole.

Systemic Vascular Resistance (SVR): The resistance offered by the peripheral circulation.

Systole: The active phase of the cardiac cycle, when the atrioventricular valve closes and contraction (systole) begins.

Trabeculae: Rounded or irregular muscular columns which project from the inner surface of the ventricles that function to reduce suction so that the ventricles can pump more effectively.

Tricuspid Valve: (Also known as the atrioventricular valve) is located between the right atrium and right ventricle.

Vasomotor Center: Is located in the medulla of the brain, and is responsible for the overall control of blood distribution and pressure throughout the body.

Layers of the Heart

The human heart is protected by two layers that envelop it. The outer layer is called the pericardium, which covers the heart. The pericardium folds in on itself at the aorta forming the epicardium of the heart. Between these layers is a small amount of fluid (10-50 mL) that affords the layers a non-stick surface (Lippincott, Williams & Wilkins, 2013).

While the epicardium forms the outer layer of the heart, the myocardium forms the middle layer and the endocardium the innermost layer. The coronary arteries travel across the epicardium. The muscular myocardium is the thickest layer and the workhorse of the heart.

The endocardium has a smooth inner surface to allow blood to flow easily through the heart's chambers. Within the endocardium of the ventricles are columns known as trabeculae. These columns project from the inner surface of the ventricles and function to reduce suction, so that the ventricles can pump more effectively. The trabeculae may sometimes be the site of pathologic clot formation known as mural (wall) thrombi.

The heart's valves are covered by the endocardium. The endocardium also has an endocrine function, releasing hormones such as endocardin - a substance that prolongs myocardial contraction.

Cardiac Chambers: On the Right

The human heart is a four-chambered pump made up of two receiving chambers called atria and two pumping chambers called ventricles. The right and left atria and ventricular chambers are separated by a septal wall or septum.

Right Atrium

The right atrium receives oxygen-depleted blood returning from the body through the superior and inferior vena cava. It is a thin walled, low-pressure system. Normal pressures in the right atrium are typically 0–8 mm Hg. It is home to the sinoatrial, or SA node, the pacemaker of the heart.

Cardiac Chambers: On the Right

Right Ventricle

The right ventricle is also a thin-walled, low-pressure chamber. It receives blood from the right atrium when the atrioventricular valve dividing the right atrium and ventricle (the tricuspid valve) is open.

When this valve is open and the chamber is resting, or filling with blood (diastole), typical right ventricular pressures are equal to pressures in the right atrium, 0-8 mm Hg.

When the valve closes and contraction (systole) begins, pressures are 15-25 mmHg, enough to pump blood forward to the lungs via the right and left pulmonary arteries. The blood is then oxygenated in the lungs.

Cardiac Chambers: On the Left

Left Atrium

The left atrium, another thin-walled, low-pressure chamber, receives oxygen-rich blood from the pulmonary circuit via the right and left pulmonary veins.

Normal resting pressures (diastolic pressures) in the left atrium are 4-12 mm Hg, less than that of the lungs. Because pressure is less in this chamber during diastole, blood is more easily returned from the higher pressure pulmonary circuit.

Cardiac Chambers: Left Ventricle

Left Ventricle

The left ventricle is a thick-walled chamber that receives blood from the left atrium and is approximately three times thicker than the right ventricle. When the atrioventricular valve dividing the left atrium and ventricle (the mitral valve) is open and the chamber is resting, or filling with blood (diastole), typical left ventricular pressures are equal to that in the left atrium, 4-12 mm Hg.

Cardiac Chambers: Left Ventricle

However, when the valve closes and contraction (systole) begins, pressures must be generated to overcome the body's systemic vascular resistance (SVR). These pressures are typically 110-130 mm Hg. When the ventricle generates enough pressure to overcome SVR, blood moves forward, out the semilunar valve (known as the aortic valve) and into the aorta.

There the blood is transported throughout the body via a network of arteries, capillaries and veins. Eventually the blood will return to the right atrium where the oxygenation process starts all over again.

Cardiac Output

About two-thirds of the atrial blood flows passively from the atria into the ventricles. When atrial contraction occurs, the atrial blood is pushed down into the ventricles. This atrial contribution is called atrial kick and accounts for approximately thirty percent of the cardiac output (Lippincott, Williams & Wilkins, 2013).

Cardiac output (C.O.) is the amount of blood ejected by the left ventricle every minute. Cardiac output equals the stroke volume times the heart rate.

The heart rate is defined as the number of times per minute that the heart beats. Heart rate increases or decreases based upon the metabolic and oxygen demands of the body. The stroke volume is the amount of blood pumped by the heart per cardiac cycle. It is measured in mL/beat. A decreased stroke volume may indicate impaired cardiac contractility or valve dysfunction and may result in heart failure. An increased stroke volume may be caused by an increase in circulating volume or an increase in inotropy, or contractile force of the ventricle.

Changes in Cardiac Output

When the heart rate or the stroke volume (amount of blood ejected with each contraction) increases, cardiac output increases. When the heart rate or the stroke volume decreases, cardiac output decreases. Cardiac output varies according to body mass, but is typically between 4-8 liters per minute.

Cardiac index (C.I.) is the ratio of cardiac output to body surface area (m2). The reference range for cardiac index is between 2.5-4.0 liters of blood per minute per meter2 (Heuer & Scanlan, 2014). There are several methods for measuring cardiac output.

Cardiac output (CO) is calculated by multiplying stroke volume x heart rate

C.O. = S.V. x H.R.

Atrial kick occurs when atrial contraction pushes blood down into the ventricles.

Test Yourself

What is the formula for cardiac output?

Cardiac output = stroke volume/heart rate

Cardiac output = stroke volume x heart rate – **Correct!**

Cardiac output = (stroke volume x heart rate) / body mass

Cardiac Valves:

Atrioventricular Valves

When blood flows through the heart, it follows a unidirectional pattern. There are four different valves within the myocardium and their functions are to assure that blood flows from the right side to the left side of the heart and always in a “forward” direction. When blood does not flow in a forward direction regurgitation or shunting may occur.

The two valves found between the atria and ventricles are appropriately called atrioventricular (A-V) valves. The tricuspid valve separates the right atrium from the right ventricle. Similarly, the mitral valve separates the left atrium from the left ventricle. The tricuspid valve is named so because of its three (tri) leaflets (cusps). Mitral valve regurgitation occurs when blood flows backward from the left ventricle into the left atrium.

Cardiac Valves: Semilunar Valves

The two remaining valves are called semilunar valves (because they look like half-moons). The valve located where the pulmonary artery meets the right ventricle is called the pulmonic valve. The aortic valve is located at the juncture of the left ventricle and aorta. Both semilunar valves prevent backflow of blood into the ventricles.

Cardiac Valve Type

Atrioventricular (AV)

Valve Name: Tricuspid and Mitral

Location: Tricuspid Valve: Separates right atrium and right ventricle

Mitral Valve: Separates left atrium and left ventricle

Semilunar

Valve Name: Pulmonic and Aortic

Location: Pulmonic Valve: Between right ventricle and pulmonary artery

Aortic Valve: Between left ventricle and aorta

Cardiac Cycle

Correlation with Heart Sounds

The first heart sound: S1

- Also known as the “Lub” of the “Lub-Dub” sound.
- It is the result of closure of the tricuspid and mitral valves during ventricular contraction.

The second heart sound: S2

- Also known as the “Dub” of the “Lub-Dub” sound.
- It occurs at the end of ventricular contraction due to the closure of the aortic and pulmonic valves.

If your computer has sound, you can visit this site to hear heart sounds:

http://www.med.ucla.edu/wilkes/intro.html

Depolarization & Repolarization

In a cardiac cell, two primary chemicals provide the electrical charges: sodium (Na+) and potassium (K+).

In the resting cell, the potassium is mostly on the inside,
while the sodium is mostly on the outside. This results in a negatively charged cell at rest (the interior of the cardiac cell is mostly negative or polarized at rest). When depolarized, the interior cell becomes positively charged and the cardiac cell will contract.

Depolarization & Repolarization

In summary, the polarized or resting cell will carry a negative charge on the inside. When depolarized, the opposite will occur. This is due to the movement of sodium and potassium across the cell membrane.

Depolarization moves an electrical wave through the myocardium. As the wave of depolarization stimulates the heart’s cells, they become positive and begin to contract. This cell-to-cell conduction of depolarization through the myocardium is carried by the fast moving sodium ions.

Repolarization is the return of electrical charges to their original state. This process must happen before the cells can be ready conduct again.

Electrical Impulse

An electrical impulse signals the heart to beat. This property is called automaticity. Automaticity means that specialized cells within the heart can discharge an electrical current without an external pacemaker, or stimulus from the brain via the spinal cord.

Note: the depolarization and repolarization phases as they are represented on the ECG.

Mechanical Impulse

The mechanical beating or contraction of the heart occurs after the electrical stimulation. When the mechanical contraction occurs, the person will have both a heart rate and a blood pressure.

The electrical cells are responsible for conducting impulses through the myocardial tissue and electrical pathways of the heart. They are responsible for the heart rate and rhythm. An ECG tracing is designed to give a graphic display of the electrical activity in the heart.

Cardiac Cell Types

The heart also has two distinct types of cells. There are electrical (conductive) cells, which initiate electrical activity and conduct it through the heart. There are also mechanical (contracting) cells, which respond to the electrical stimulus and contract to pump blood.

The contracting or myocardial "working cells" contain contractile filaments. When these cells are electrically stimulated, filaments slide together and the myocardial cell contracts and the atria or ventricular chambers contract. This is how we get our pulse and blood pressure.

Test Yourself

The heart has both mechanical and electrical cells.

True – **Correct**

False

Sinoatrial (SA) Node

The sinoatrial node (also called the SA node or sinus node) is a group of specialized cells located in the posterior wall of the right atrium. The SA node normally depolarizes or paces more rapidly than any other part of the conduction system. It sets off impulses that trigger atrial depolarization and contraction. Because the SA node discharges impulses quicker than any other part of the heart, it is commonly known as the natural pacemaker of the heart.

After the SA node fires, a wave of cardiac cells begin to depolarize. Depolarization occurs throughout both the right and left atria (similar to the ripple effect when a rock is thrown into a pond). This impulse travels through the atria by way of inter-nodal pathways down to the next structure, which is called the AV node.

The SA node is not only the primary pacemaker of the heart but it also triggers atrial depolarization and the contribution of the atrial kick. The heart has one dominant pacemaker (the SA node) and two back up pacemakers. One back-up pacer is located in the area near the bundle of His, the other back-up pacer is located in the ventricles along the Purkinje fibers.

Atrioventricular (AV) Node and AV Junction

The next area of conductive tissue along the conduction pathway is at the site of the atrioventricular (AV) node. This node is a cluster of specialized cells located in the lower portion of the right atrium, above the base of the tricuspid valve. The AV node itself possesses no pacemaker cells.

The AV node has two functions. The first function is to DELAY the electrical impulse in order to allow the atria time to contract and complete filling of the ventricles. The second function is to receive an electrical impulse and conduct it down to the ventricles via the AV junction and bundle of His.

Bundle of His

After passing through the AV node, the electrical impulse enters the bundle of His (also referred to as the common bundle). The bundle of His is located in the upper portion of the interventricular septum and connects the AV node with the two bundle branches. If the SA node should become diseased or fail to function properly, the bundle of His has pacemaker cells, which are capable of discharging at an intrinsic rate of 40-60 beats per minute.

The AV node and the bundle of His are referred to collectively as the AV junction. The bundle of His conducts the electrical impulse down to the right and left bundle branches.

The right bundle branch spreads the wave of depolarization to the right ventricle. Likewise, the left bundle branch spreads the wave of depolarization to both the interventricular septum and the left ventricle. The left bundle further divides into three branches or fasicles. The bundle branches further divide into Purkinje fibers.

Purkinje Fibers

At the terminal ends of the bundle branches, smaller fibers distribute the electrical impulses to the muscle cells, which stimulate contraction. This web of fibers is called the Purkinje fibers. The Purkinje fibers penetrate about 1/4 to 1/3 of the way into the ventricular muscle mass and then become continuous with the cardiac muscle fibers. Electrical impulses spread rapidly through the right and left bundle branches and Purkinje fibers to reach the ventricular muscle, causing ventricular contraction, or systole.

Purkinje fibers within the ventricles also have intrinsic pacemaker ability, however this area of the myocardium can only pace at a rate of 20-40 beats per minute.

The further the distance from the SA node, the slower the backup pacemakers become. For example, if the heart rate is 30 beats per minute (generated from the ventricular back-up pacemaker), the blood pressure is likely to be low and the patient may be quite symptomatic.

Summary of Pacemaker Functions

The heart is designed with a system of one dominant and two back-up pacing systems.

Pacemaker Hierarchy: Level 1 (Normal)

Location: SA node

Pacing Rate: 60-100 beats/minute

Pacemaker Hierarchy: Level 2 (Back-up System)

Location: Bundle of His/ AV node/ Junction

Pacing Rate: 40-60 beats/minute

Pacemaker Hierarchy: Level 3 (Lowest Back-up System)

Location: Purkinje fibers within ventricles (typically called the ventricular pacemaker)

Pacing Rate: 20-40 beats/minute

The Coronary Arteries

The coronary arteries receive their name for the “crown” they form over the heart. These arteries are the right coronary artery (RCA) and left coronary artery (LCA) and they arise off the aorta at the sinus of Valsalva.

When the aortic valve closes at the beginning of diastole, the sinus of Valsalva distends and blood flows into the RCA and LCA.

RCA (Right Coronary Artery)

The RCA arises from the right side of the aorta and follows the atrioventricular groove between the right atrium and the right ventricle. It extends to the back of the heart, forming the posterior descending artery. The RCA has two branches, the posterior descending artery and the right marginal artery. The main portion of the RCA provides blood to the right side of the heart. This includes the right atrium and the right ventricle, much of conduction system and the inferior and posterior left ventricle. The RCA supplies blood to the SA node (in fifty-five percent of the population) and the AV node (in ninety percent of the population). Occlusion of the right coronary artery can lead to inferior and posterior MIs. Bradycardia and arrhythmias are commonly seen in these MIs.

LCA (Left Coronary Artery)

The LCA arises off of the left side of the aorta. Known as the left main coronary artery, it divides into two separate arteries, the left anterior descending (LAD) and the circumflex

Left Anterior Descending (LAD) Artery

The LAD travels down the heart between the right ventricle and left ventricle to the apex and turns back up the heart. It is the main blood supply to left ventricle, septum, and anterior wall. Diagonal arteries arise off of the LAD.

Circumflex Artery

The circumflex artery curves around left side of the heart between the left atrium and the left ventricle. It supplies blood to the posterior surface of the heart. It supplies blood to the SA node (in forty-five percent of the population) and the AV node (in ten percent of the population). Its marginal branches provide the left lateral ventricle and the posterior left ventricle with its blood supply.

Test Yourself

The LCA is known as the Left Circumflex Artery.

True

False **- Correct!** The LCA is the Left Coronary Artery.

Coronary Blood Flow

Two-thirds of coronary blood flow occurs during diastole, or when the heart is at rest. Five percent of cardiac output goes to the coronary arteries. Seventy percent of oxygen is extracted by the myocardial tissues of the heart, in comparison to the rest of the body at twenty-five percent. During times of extreme demand, the coronary arteries can dilate up to four times greater than normal to increase the supply of oxygen to the myocardial tissues.

The de-oxygenated blood from the myocardium is collected in the coronary sinus. This large vein then returns the de-oxygenated blood to the right atrium.

Coronary Artery Disease

Patients with coronary artery disease have fixed lesions that cannot dilate to meet increased demand. This leads to angina and coronary dysfunction, which may eventually lead to myocardial infarction.

Bradycardias

Bradycardias increase diastolic filling time. This is why cardiac patients can tolerate bradycardias better than tachycardias.

Location of Myocardial Infarction

A myocardial infarction (MI) occurs when blood flow to a specific region of the heart is blocked for a period of time long enough to cause tissue necrosis (death). Most MIs are caused by a thrombosis (blood clot) in one of the coronary arteries.

Select each location to identify the specific coronary artery that is affected in a myocardial infarction.

Inferior

Coronary Artery: Right Coronary Artery

Anterior or Anteroseptal

Coronary Artery: Left Anterior Descending Artery

Lateral MI

Coronary Artery: Left Circumflex

Posterior

Coronary Artery: Left Circumflex or Right Coronary Artery

The Arterial System

The arterial system carries about thirteen percent of the body's blood volume at any given time. The heart pumps blood out through one major artery, the aorta. The aorta branches and these branches further divide into smaller arteries known as arterioles. Arterioles contain smooth muscle, are innervated by the autonomic nervous system and can constrict and dilate to regulate blood supply to tissues. Arterioles are largely responsible for our systemic vascular resistance (SVR). Eventually, the arterioles divide enough that they become capillaries – where the exchange of oxygen, carbon dioxide, and nutrients occurs.

The Arterial System

Arteries are composed of three layers:

- Intima (the inner layer of epithelial cells)
- Media (the muscular middle layer)
- Adventitia (the tough outer layer)

The media layer helps the heart pump the blood. When the heart beats, the artery expands as it fills with blood. When the heart relaxes, the artery contracts, exerting a force that is strong enough to push the blood along. This rhythm between the heart and the artery results in successful circulation of the blood to the body.

Test Yourself

The adventia is what layer of the artery?

The adventia is the inner layer of epithelial cells.

The adventia is the muscular middle layer.

The adventia is the tough outermost layer of the artery. - **Correct**

Capillaries

Blood spends approximately 0.5 seconds in capillaries. Capillaries are only about one cell thick. The exchange of oxygen, carbon dioxide, and nutrients takes place through this very thin wall. At this cellular level, the red blood cells inside the capillaries release their oxygen. This oxygen then passes through the wall and into the surrounding tissue. Simultaneously, the tissues release their waste products, such as carbon dioxide. These wastes pass through the wall and into the red blood cells. The red blood cell transports the wastes to the lungs, liver and other organs to be processed for their excretion.

Additionally, capillaries have both pre and post capillary sphincters that have a high degree of intrinsic tone that are independent of neurohormonal controls. Capillaries also auto-regulate to meet metabolic needs of surrounding tissues.

Test Yourself

Capillaries are only TWO cells thick.

True

False - **Correct**. Capillary walls are only one cell thick to allow for the exchange of gases and nutrients.

Venous System

Blood leaving the capillaries returns to the heart through the venous system beginning with venules and progressing to larger and larger veins. The larger veins lead to the superior and inferior vena cavae which enters the right atrium. Veins are highly distensible, thin walled vessels that act as a volume reservoir for circulatory systems.

At any given time, the veins carry about fifty percent of the body's blood volume. Veins are very much like arteries however they transport blood at a much lower pressure than arteries. The veins transport blood back to the lungs and heart. Veins have valves that help to keep blood moving back to the heart. The vein valves provide footholds for the blood as it travels against gravity towards the heart. For example, blood returning to the heart from the foot has to travel against gravity.

The venous valves and muscle contractions of the leg prevent backflow of blood.

Venous Capacity

Drugs that increase venous capacity (diuretics, morphine, and nitroglycerin) will decrease preload, thus decreasing the amount of blood returning to the right side of the heart. High Fowlers also increases venous capacity & decreases preload.

The supine position decreases venous capacity and increases preload, or the amount of blood returning to the right side of the heart.

Neurohormonal Control of the Heart

The brain and central nervous system control the body through two pathways - the somatic & autonomic nervous systems. The somatic nervous system is typically under voluntary control. The autonomic nervous system is not voluntary and regulates the activities of the internal organs including the heart.

The autonomic nervous system has two main parts, the sympathetic and the parasympathetic systems. These two "opposite" systems often operate in opposition to each other. Many internal organs are stimulated by both systems. When one stimulates an organ, the other tends to depress the organ.

The sympathetic nervous system is responsible for the "fight-or-flight" response. This response prepares us for emergency situations.

The parasympathetic nervous system, oppositely, tends to inhibit these reactions. The response of our body depends on the proportionate strength of stimulation supplied by each system at any given instance.

Test Yourself

The heart is stimulated by what system?

The heart is stimulated by what system?

The parasympathetic system

By both sympathetic and parasympathetic systems – **Correct**

Sympathetic Nervous System of the Heart

Activation of the sympathetic nervous system, increases heart rate (positive chronotropy), increases contractility (positive inotropy), and increases conduction velocity (positive dromotropy). Additionally, in blood vessels, sympathetic activation constricts arteries and arterioles. This increases systemic vascular resistance (SVR, increases central blood flow and decreases distal blood flow). Sympathetic activation causes blood to be shunted away from the periphery to the heart, brain and skeletal muscles. Sympathetic activation also produces an effect on the body's venous system causing a decrease in venous blood volume and an increases venous pressure.

The overall effect of sympathetic activation is to increase cardiac output, systemic vascular resistance (both arteries and veins), and arterial blood pressure. Enhanced sympathetic activity is particularly important during exercise, emotional stress, and during hemorrhagic shock.

The overall effect of activation of the sympathetic nervous system is to increase:

Heart rate

Cardiac output

Systemic vascular resistance

Parasympathetic Nervous System of the Heart

When the parasympathetic system of the heart is activated, it acts via the vagus nerve to:

- Decrease heart rate (negative chronotropy)
- Decrease contractility (negative inotropy)
- Decrease conduction velocity (negative dromotropy)

Most blood vessels in the body do not have parasympathetic innervation.

Baroreceptors

Baroreceptors are sensory nerve endings that detect changes in pressures in the walls of blood vessels. They are located in the aortic arch, the carotid bodies of the external carotid arteries, the pulmonary artery and the atria. They respond to changes in blood pressure.

The baroreceptors of the aortic arch have a high threshold pressure and are less sensitive than the carotid sinus receptors.

The baroreceptors of the carotid sinus typically respond to pressures ranging from 60-180 mmHg. These receptors are the dominant receptors and work by sensing the "mean" arterial blood pressure.

This "set point" changes during hypertension, heart failure, and other chronic disease states. When there is an acute increase or decrease in mean arterial pressure, the baroreceptors alter their firing rate.

Baroreceptors

For example, hypotension decreases the firing rate of the carotid baroreceptors, and results in less inhibition of sympathetic response. This action increases sympathetic activity which leads to increased blood pressure, by increasing vasoconstriction (increased SVR), increasing heart rate and increasing the force of contraction of the heart. These changes will result in increase in arterial pressure.

Alternatively, an acute increase in arterial pressure increases the firing rate of the baroreceptors which increases the inhibition of sympathetic activity in the brain (medulla). When sympathetic stimulation is inhibited, bradycardia occurs, and decreased conductivity and decreased contractility of the myocardium results.

Test Yourself

Baroreceptors respond to changes in temperature.

True

False - **Correct**! Baroreceptors respond to changes in blood pressure.

Chemoreceptors

Chemoreceptors are located both peripherally and centrally. Their role is to detect abnormal changes in oxygen, carbon dioxide and hydrogen ion concentration in the blood stream.

The body's major chemoreceptors are located in the carotid bodies of the external carotid arteries near the bifurcation of the internal carotid arteries. These carotid bodies continually sense oxygen, carbon dioxide, and hydrogen ion concentration in the blood. When these receptors are stimulated, they act on the respiratory system to increase or decrease the rate of respiration, in order to correct the perceived disturbance.

Respiratory arrest and circulatory shock dramatically increase chemoreceptor activity, leading to increased sympathetic stimulation to the heart and vasculature via activation of the vasomotor center.

Vasomotor Center Activity

Vasomotor Center

The vasomotor center in the medulla of the brain is responsible for the overall control of blood distribution and pressure throughout the body. Impulses from the vasomotor center typically cause vasoconstriction everywhere except for the coronary and skeletal arteries, where they cause vasodilation.

Hormonal Influences on the Cardiovascular System

Certain hormones and substances help the body auto-regulate its blood pressure:

Vasopressin or antidiuretic hormone (ADH) is released from the pituitary gland in the brain, when the baroreceptors sense a fall in blood pressure. Its effect on vessels is to cause vasoconstriction – which usually results in an increased blood pressure.

Endothelin is released from the endothelial cells of the vasculature after vascular damage. It produces vasoconstriction of the underlying vascular smooth muscle and prevents blood loss

Atrial natriuretic peptide (ANP) is released from the atria of the heart and endothelium due to an increase in pressure or venous return to the atria and excess stretching of the vessels. Its net effect is to relax vascular smooth muscle and decrease blood pressure.

Nitric oxide is also released from the endothelium of the vasculature when stretching increases, producing a net effect of vasodilation. Nitric oxide is the basis of the therapeutic action of nitroglycerine.

Renin-Angiotensin System

When the kidneys sense a decrease in blood pressure, the renin-angiotensin system is activated. This system has the net effect of increasing organ perfusion and arterial blood pressure, and is very effective when there is a blood loss.

However, when the system is activated due to a pathologic condition, such as heart failure, the system itself becomes pathological, resulting in an increase in blood pressure that may be detrimental.

The mechanisms of action of many antihypertensive drugs is the interference with specific pathways within this system, such as ACE Inhibitors and beta blockers.

Conclusion

Knowledge of the anatomy and physiology of the complex structures and mechanisms of the cardiovascular system involves not only the physical structures but the electrical and hormonal influences that make them work.

As a caregiver, an awareness of the multiple factors that have the potential to influence and alter the regulation of the heart is an extremely important factor to consider.

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References

American Association of Critical Care Nurses (2005). The Cardiovascular System. J. Alspach. Core curriculum for critical care nursing (6th edition). Philadelphia: Saunders.

Cable, Christopher. (2011). Auscultation Assistant. Retrieved September 21, 2006 and April 10, 2011 from www.med.ucla.edu/wikes/intro.html

Heuer, A. & Scanlan, C. (2014). Wilkins' Clinical Assessment in Respiratory Care, Seventh Edition. Missouri: Elsevier Mosby.

Lippincott, Williams & Wilkins (2005). ECG Interpretation Made Incredibly Easy. Third Edition. PA: Wolter Kluwer Health.

Lippincott, Williams & Wilkins (2013). Anatomy & Physiology Made Incredibly Visual. Fourth Edition. PA: Wolter Kluwer Health

Sherwood, L. (2010). Human physiology: From cells to systems (7th edition). Belmont, California: Wadsworth.

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