Heart

Development

The heart requires only 6 or 7 days to develop

Heart development is first apparent at the 18th or 19th day of embryonic development in the cardiogenic area of the mesodermal layer

We first see the development of a heart tube which undergoes dilations and constrictions to form the various regions of the heart

At this stage there are 5 regions of the heart
1. truncus arteriosus – will form a partition between the aorta and the pulmonary trunk
2. bulbus cordis – incorporated into the walls of the ventricles
3. ventricle
4. atrium
5. sinus venosus – forms coronary sinus and a portion of the wall of the right atrium

these structures pump blood, however the actual partitioning of the heart chambers begins during the 4th week and is completed by the end of the 5th week of embryonic development. It is during this time that many congenital heart problems arise.

Development of the major arteries

occurs along with heart development

Aortic arches – development is very complex

formation of the aortic arches is associated with the pharyngeal pouches and the branchial arches in the neck region

6 aortic arches arise from the truncus arteriosus. They are not all present at the same time, and none of them persists in entirety through fetal development.

the transformation of the 6 aortic arches into the basic adult arterial arrangement occurs during the 6th to 8th week of embryonic development.

The 1st and 2nd pairs of arches degenerate before the formation of the 6th pair.

the 3rd pair of arches form the common carotid and internal carotid arteries

the right 4th arch forms the base of the right subclavian artery

the left 4th arch contributes to part of the aortic arch

the 5th pair of arches degenerates

the left 6th arch forms part of the left pulmonary artery and the ductus arteriosus

the right 6th arch form the right pulmonary artery.

Cardiac Muscle (revisited)

is branched

is striated

has centrally located nuclei (note the perinuclear spindle)

has intercalated discs

exhibits rhythmical involuntary contractions

Position of the heart in the thorax

The thorax is divided into 7 different regions. These are the two pleural cavities and the 5 regions of the mediastinum. The word "mediastinum: literally means the "middle space."

Mediastinum – from sternum to vertebral column

1. anterior mediastinum, is located between the sternum and the pericardial sac

2. posterior mediastinum, is located between the pericardial sac and the vertebral column

3. superior mediastinum, is located superior to a line drawn from the sternal angle to the inferior border of the 4th thoracic vertebrae.

4. middle mediastinum is basically outlined by the pericardial sac. The main structure in middle mediastinum is the heart.

Borders of the Heart

1. Apex – tip of left ventricle. Points inferiorly, anteriorly, and to the left. Lies at the 5th intercostals space.

2. Left border – Mostly left ventricle with some left atrium at the upper end. From left 5th costochondral junction to left 2nd intercostal space.

3. Superior border – great vessels enter/leave. A line drawn from left 2nd intercostals space to 3rd right costal cartilage.

4. Base – mostly right atrium. Points superiorly, posteriorly, and to the right.

5. Right border – right atrium. A line drawn from right xiphisternal articulation to middle of right 3rd costal cartilage

6. Inferior border – right ventricle and some left ventricle

Auscultation – Listening to heart sounds

The cardiac notch leaves a part of the fibrous pericardium uncovered by lung tissue. This area, on the left anterior chest, is called the area of superficial cardiac dullness. This is because it yields a dull note upon percussion (tapping with the finger).

Pericardium – Is a connective tissue sac surrounding the heart. It has two portions

1. fibrous pericardium – made of heavy connective tissue. Anchors the heart, prevents overdistension, provides a protective membrane.

2. Serous pericardium – thin, double layer

a. parietal layer – directly beneath the fibrous pericardium

b. visceral layer – also called epicardium. Attached to the muscles of the heart.

3. Pericardial fluid – ultrafiltrate of plasma located between the two layers of serous pericardium. This potential space is called the pericardial cavity. The fluid prevents friction between the two layers.

4. Clinical inflammation (pericarditis) – pericardial fluid can build up and become life threatening. Can cause cardiac tamponade which is heart failure due to compression. The compression affects the return of blood to the left atrium by squeezing off the pulmonary veins.

Vessels to the pericardium

The main arterial supply to the pericardium is derived from the internal thoracic arteries via the pericardiacophrenic and musculophrenic branches. There are also pericardial branches from the bronchial, esophageal, and superior phrenic arteries.

Note: the visceral layer of the serous pericardium (epicardium) is supplied by the coronary arteries.

The veins draining the pericardium are tributaries of the azygous system and also pericardiacophrenic veins which enter the internal thoracic veins.

Nerves of the pericardium – are derived from the vagus and phrenic nerves and the sympathetic trunk.

The Heart

The heart is responsible for pumping blood through the entire body. The heart pumps blood through the aorta to all parts of the body. The heart also pumps blood to the lungs to carry out external respiration. To accomplish this, the heart is comprised of 4 chambers. There is a right atrium and a right ventricle, and a left atrium and left ventricle.

There are some features that are specific to the various chambers of the heart. Some of these features will be discussed following a discussion of the pulmonary circuit, the blood flow between the heart and lungs.

The Pulmonary circuit – blood flow between the heart and lungs

The blood flow within the heart is not the same in a fetus as it is in post term infant thought adulthood.

The passage of blood through the heart following birth is as follows:

Deoxygenated blood returning to the heart from the body will enter the right atrium. This deoxygenated blood is coming to the heart from the superior vena cava and the inferior vena cava. A small amount of blood is also coming from the coronary sinus and the anterior cardiac veins.

Once the right atrium is filled with blood, its walls will contract and push the blood down through the right atrioventricular valve (also called the tricuspid valve) to the right ventricle. When the right ventricle is filled with this deoxygenated blood, its walls will contract from the bottom up and send the blood up past the conus arteriosus and through the pulmonary semilunar valve, into the pulmonary trunk. At this point the pulmonary trunk divides to form the right and left pulmonary arteries, which will carry the deoxygenated blood into the lungs. Essentially the right side of the heart is dedicated to pumping deoxygenated blood.

Oxygenated blood will return to the heart from the lungs via four pulmonary veins. Two from the right lung, and two from the left lung. The pulmonary veins will enter into the left atrium.

When the left atrium is filled with blood, its wall will contract and send the blood down through the left atrioventricular valve (also called the bicuspid valve or the mitral valve) into the left ventricle. When the left ventricle is full of blood its walls will contract and send the blood up through the aortic semilunar valve into the ascending aorta. Essentially the left side of the heart is dedicated to pumping oxygenated blood.

The two major reasons to send blood through the lungs after birth is to expel carbon dioxide and bring in oxygen. In other word, exchanging gases with the external air. During fetal life there is no air in the lungs, so passing blood through the lungs will not result in gas exchange. The gas exchange needed by the fetus occurs at the placenta. Since there is very little necessity to send blood through the lungs during fetal life, there is a mechanism that almost completely bypasses the lungs.

In fetal life the blood still enters the right atrium via the superior and inferior vena cava and the coronary sinus and anterior cardiac veins. When the right atrium contracts, some of this blood will follow the adult flow pattern and pass down to the right ventricle, but much of that blood with pass directly to the left atrium by passing through and opening in the wall between the two atria. This wall is known as the interatrial septum and the opening is referred to as the foramen ovale. Blood passing through the foramen ovale has bypassed the lungs.

The blood that passed from the right atrium down to the right ventricle will now follow the adult flow pattern until to reaches the pulmonary trunk. At this point the is a connection between the pulmonary trunk and the aortic arch. This connection is known as the ductus arteriosus. It allows blood to pass directly from the pulmonary trunk to the aorta, thereby bypassing the lungs.

Some of the blood will follow the normal adult flow pattern because it is essential that the pulmonary circuit be “tested” to ensure that blood flowing to the lungs from the heart, does return to the heart. If this circuit is not complete, as soon as the umbilical cord is cut, the infant would not be able to accomplish gas exchange and death would occur within a minute.

Following birth, the mechanisms for bypassing the lungs are no longer needed, and if they persist can be very problematic. The body has mechanisms for making changes to this system.

Shortly after birth, pressure changes within the thoracic cavity, some caused by the inflation of the lungs, will cause the two cusps of the foramen ovale to come into approximation with each other, thereby closing this foramen. This will leave a depression in the interatrial septum that is referred to as the fossa ovalis, when viewed in the right atrium. The opposite side of the depression, as seen in the left atrium, is referred to as the

fossa secundum. It is important to note that closing of the foramen ovale is not of immediate concern in an infant. Although there will be mixing of oxygenated and deoxygenated blood, the infant doesn't have a high oxygen demand, due to low levels of physical activity. But if the foramen persists after the first few years of life, medical intervention will be necessary.

Within the first year of life the ductus arteriosus will also undergo changes. Under hormonal influence the tissue forming this duct will undergo changes that will essentially turn the remnants of the duct into a ligament. This ligament is referred to as the ligamentum arteriosum. In some instances the ductus arteriosus does not undergo the changes to form the ligamentum arteriosum. In this case medical intervention will be necessary. This intervention essentially consists of putting a ligature around the ductus.

Heart Chambers and their contents/functions.

Atria: The atria are essentially blood receiving chambers. They are generally divided into two portions.

1. the sinus venarum – the smooth portion of the atria. This is the remnant of the embryonic sinus venosus

2. the pectinate muscles or musculi pectinati, is a rough muscle texture found along the internal surface of anterior wall of the right atrium and in all of the right auricle. On the left side of the heart it is only found in the left auricle. Note that the auricles are ear like appendages that are attached to the right and left atria.

Externally these two, the sinus venarum and the pectinate muscles, are separated by a groove called the sulcus terminalis

Internally these two are separated by a ridge called the crista terminalis

The right atrium will also have the fossa ovalis and well as the openings for the coronary sinus, anterior cardiac veins, superior vena cava, and inferior vena cava.

The left atrium has the four openings for the pulmonary veins as well as the fossa secundum.

Ventricles: are essentially blood delivery chambers.

Trabeculae Carnae: essentially means a lattice work or meat. In this case, cardiac meat, or myocardium. This gives the majority of the ventricular chambers a rough texture. Rising out of the ventricular walls are smooth fingerlike projections called papillary muscles. The papillary muscles are attached to tendinous chords called chordae tendineae. The other end of

these cords attaches to the valve cusps of the right atrioventricular valve or the left atrioventricular valve. Together the papillary muscles and the chordae tendineae form a structure referred to as the sub valvular apparatus. The papillary muscles will contract when tension is put on them from the chordae tendineae. This tension is due to pressure being put on the valve cusps during ventricular contraction, as the valves work to prevent flow of blood back up into the atria. Essentially the sub valvular apparatus functions to prevent a prolapsed valve.

Right ventricle: The right ventricle has two features that are not found in the left ventricle

1. the conus arteriosus: This is a smooth area located at the top of the right ventricle leading up to the pulmonary semilunar valve. This smooth area works to not impede the flow of blood leaving the right ventricle.

2. the septomarginal trabeculae, also known as the moderator band. This is a special piece of the trabeculae carnae which carries a portion of the right branch of the atrioventricular bundle from the interventricular septum over to the right wall of the right ventricle. This acts as a shortcut for the conduction system of the heart so that the right wall of the right ventricle begins to contract before the rest of the ventricle, thereby directing the blood up into the conus arteriosus rather than directly against the right atrioventricular valve.

Cardiac Skeleton

The heart wall consists of fibrous connective tissue that forms the skeleton of the heart. It forms a foundation for attachment of heart valves and cardiac muscle fibers and also serves as an electrical insulator between the atria and ventricles.

1. Fibrous rings. These provide and anchor point for the various valve cusps

a. right atrioventricular

b. left atrioventricular

c. pulmonary

d. aortic

2. trigones

a. right fibrous trigone – formed by fusion of the fibrous connective tissue of the left atrioventricular, aortic, and right atrioventricular fibrous rings.

b. left fibrous trigone – formed by fusion of fibrous connective tissue of aortic and left atrioventricular fibrous rings.

c. conus tendon – formed by fusion of fibrous connective tissue of aortic and pulmonary fibrous rings.

Vessels of the Heart

1. Coronary Arteries. Initially there are two coronary arteries, the right and left coronary arteries. All other arteries to the heart branch from these two arteries.

a. Right coronary artery – the right coronary artery is the very first branch of the ascending aorta. It will pass around the right side of the heart traveling in the sulcus between the right atria and right ventricle. The very first branch of this artery is a small branch that will pass to the area of the sinoatrial node. This is known as the sinoatrial nodal branch of the right coronary artery. As the right coronary artery passes along the front of the heart it sends muscular branches mainly to the right ventricle. It also has a branch that travels along the right side of the heart, known as the marginal branch of the right coronary artery. It then passes to the posterior side of the heart where it may join with other vessels to form the posterior interventricular artery, or may become the posterior interventricular branch of the right coronary artery.

b. Left coronary artery – The left coronary artery is the second branch of the ascending aorta. It will branch from the ascending aorta and pass behind the pulmonary trunk toward the left side of the heart. While passing behind the pulmonary trunk it will give off a small branch that will pass to the area of the sinoatrial node. This is known as the sinoatrial nodal branch of the left coronary artery. As soon as the left coronary artery emerges from behind the pulmonary trunk it will branch into an anterior interventricular artery and a circumflex artery. Both of these arteries have muscular branches. The circumflex artery will give rise to a branch often referred to as the left marginal branch of the circumflex artery. The circumflex artery will then continue around the back of the heart to join with other vessels to form the posterior interventricular artery, or may become the posterior interventricular branch of the circumflex artery

It is important to note that the coronary arteries are often given alternate names in a clinical setting. For example, the anterior interventricular artery is often referred to as the left anterior descending artery. The name makes good sense because the artery does pass to the left and anterior side of the heart and does pass down toward the apex of the heart.

2. Cardiac Veins – are the veins that collect deoxygenated blood from the myocardium and return it to the circulation. There are two small veins that drain

blood from the upper anterior wall of the right ventricle directly into the front of the right atrium. The remainder of the veins draining the myocardium will ultimately drain into the coronary sinus system. On the right side of the heart there is a small cardiac vein that will drain blood from the right margin of the right ventricle. This vein will ascend to the sulcus between the right atrium and right ventricle. Once it enters the sulcus it will travel around the right side of the heart, along the superior portion of the back side of the right ventricle to enter the coronary sinus.

The great cardiac vein begins near the apex on the anterior side of the heart. It will ascend the front of the heart overlying the interventricular septum. It then travels around the left side of the heart to reach the coronary sinus. On its way around the left margin of the heart it picks up blood from the marginal vein. Near the junction of the great cardiac vein and the coronary sinus, a left posterior ventricular vein, which is not present in most people, may join the system.

The middle cardiac vein ascends the posterior aspect of the heart overlying the posterior interventricular septum. It drains into the coronary sinus.

3. Some clinical terms related to the heart can coronary blood flow.

a. ischemia – is a reduced oxygen supply to the heart. It weakens but does not kill heart cells.

b. myocardial infarction (heart attack) –this is death of tissue due to interrupted blood supply. Damage my result from restoration of blood flow. During interrupted blood flow the effected tissue produces an enzyme called xanthinoxidase. When (if) blood flow is restored, the enzyme reacts with the oxygen in the blood to form superoxide free radicals which cause tissue damage. Treatments is by administration of superoxide dismutase or **allopurinol** to prevent formation of the superoxide free radicals.

Conduction system and EKG

The heart exhibit auto rhythmicity, which means it beats on its own. This is accomplished by two “pacemakers” found within the heart.

1. the sinoatrial node, which is often referred to as the pacemaker of the heart, is often abbreviated as the SA node. It is located in the upper right portion of the right atrium. This node has ion channels that “leak” ions at a fairly consistent rate. When enough ions have leaked across them membrane to reach a depolarization threshold, a wave of depolarization will leave this node and spread across the atria via internodal tracts. The result is a depolarization of the muscle walls of the atria, causing them to contract. At the same time, ion pumps actively pump the “leaked” ions back across the membrane, thereby resetting the system.

2. the atrioventricular node, often abbreviated the AV node, is found in the lower left portion of the right atrium near the right ventricle. It can generate a rhythm by itself, but normally responds to the depolarization it receives for the internodal tracts.

3. the atrioventricular bundle and bundle branches. The atrioventricular bundle is a special band of tissue that carries the wave of depolarization from the AV node down in to the myocardium of the ventricles. The bundle quickly branches into the right and left bundle branches. These bundle branches carry the wave of depolarization down toward the apex of the heart. This wave of depolarization passing in the bundle branches does not stimulate contraction of the ventricles. This is necessary because there needs to be a mechanism where the ventricles will essentially contract from the bottom up.

3. Conduction myofibrils, also known as Purkinje fibers, are branches off of the bundle branches and are responsible for stimulating the contraction of the myocardium.

It is important to note that the heart itself doe not have nerves. It has specialized conduction pathways. This help to maintain the auto rhythmicity of the heart.
1. electrical system of the heart (sinoatrial and atrioventricular nodes)

Heart Rate

Although the heart exhibits auto rhythmicity there are mechanisms that can speed up or slow down the heart rate.

The autonomic nervous system is used to increase or decrease heart rate.

a. the cardioacceleratory center in the medulla oblongata gives rise to the cardiac nerve, which is a portion of the sympathetic nervous system. This nerve uses norepinephrine to stimulate the sinoatrial and atrioventricular nodes to increase heart rate.

b. the cardioinhibitory center in the medulla oblongata gives rise to the Vagus nerve, which is a portion of the parasympathetic nervous system, sends Acetylcholine to the sinoatrial and atrioventricular nodes to decrease heart rate.

These both work based on feedback to brain via baroreceptors.

Anomalies with heart rate

Atrial fibrillation – is a condition where there is accelerated heart rhythm in the atria but not in the ventricle, thus the heart rhythm is not synchronized.

Tachycardia, also known as Tachyarrhythmia, is defined as a resting heart rate greater then 100 beats per minute. In this condition the heart beats faster than it can fill with blood, so blood flow to the body is greatly reduced.

EKG or electrocardiogram

The EKG is a chart that represents the electrical activity given off by the heart tissue as it goes through a cardiac cycle.

The EKG is divided into various named portions. These are:

P wave – upward deflection – this represents depolarization of atrial fibers through stimulation of the sinoatrial node. A missing or abnormal P wave indicates dysfunction of the sinoatrial node.

QRS Complex – upward deflection – the heart is in systole. blood is being ejected from the ventricles. Essentially represents depolarization of the ventricles. When abnormal it generally indicates ventricular problems. An enlarged R spike usually means enlarged ventricles.

T Wave – represents ventricular repolarization. Altered T waves my mean an arteriosclerotic heart.

P-R interval – the time between the top of the P wave and the top of the QRS complex. This indicates the time it takes for the atrial depolarization to reach the ventricles. A prolonged P-R interval suggests a conduction delay in the atrioventricular node or an atrioventricular bundle blockage.

ST Segment –the area of the EKG between the downward deflected S and entering into the T wave. This line is depressed, or lower, when the heart receives insufficient oxygen and is elevated, or higher, in acute myocardial infarction.

Herat Defects to discuss

1. patent foramen ovale – this condition exists when the foramen ovale did not completely form a fossa ovalis. Some blood still passes through the area.

2. interventricular septal defect – this condition occurs when there is a hole in the wall between the two ventricles, the interventricular septum. This condition results from a failure of the top portion of the septum, which is growing downward, to fuse with the bottom portion of the septum, which is growing upward. The condition results in blood from the ventricles intermixing. Generally deoxygenated blood from the right ventricle will pass into the left ventricle.

3. patent ductus arteriosus – this condition results from the failure of the ductus arteriosus to transform in to the ligamentum arteriosus.

4. tetrology of Fallot – As the name implies, there are 4 anomalies associated with this condition. For our purposes we only need to know one of them, that is that the aorta arises from both the right and left ventricles