Cardiac Physiology.

Learning Package

Cardiac Physiology

The heart is the centre of the cardiovascular system

- It is a biochemically driven pump.
- It is located in the mediastinum between the sternum and the spinal column.
- Its size approximates the size of the persons closed fist.
- Enclosed in pericardium, two layers.
    - Fibrous pericardium (outer layer).
    - Serous pericardium, two layers, visceral and parietal separated by potential space containing pericardial fluid.
- has three layers,
    - Epicardium (coronary arteries transverse).
    - Myocardium (muscle).
    - Endocardium (lines heart chambers).

Myocardium:

There are three types of cardiac muscle.

- Atrial muscle.
- Ventricular muscle.
- Conductive muscle fibres contract only feebly but allow rapid conduction of electrical impulses.

Sarcomere; contractile unit of muscle. Is made up of myosin and actin filaments, troponin part of the actin filament is thought to combine with **Ca**$^{++}$ and cause the filaments to intertwine and slide along each other to cause contractions. Ca^{++} is seen to be the catalyst for muscle contraction so its importance as an ion can not be overlooked. The strength of myocardial contraction is seen to be dependent on available intracellular Ca^{++}.

Did you know?

In myocardial infarction measurements of troponin I, a cardiac enzyme, are used to ascertain if myocardial injury has occurred

Normal structure:

Made up of two sides and four chambers;

1] Right atrium;

- receives deoxygenated blood from the systemic circulation via the superior and inferior venae cavae and the coronary circulation via the coronary sinus
- Thin walled structure. (2mm)
- Pumps blood into the right ventricle.

2] Right Ventricle;

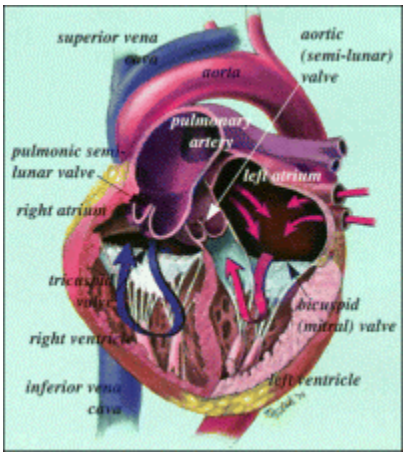
- Receives unoxygenated blood via the right atrium.
- Thin walled. (3-5mm)
- Pumps blood into the pulmonary artery and the lungs for oxygenation.

3] Left Atria;

- Receives oxygenated blood from the lungs via the four pulmonary veins.
- Thin walled. (3mm)
- Pumps blood into the left ventricle.

4] Left Ventricle;

- Receives oxygenated blood from the left atrium.
- Thick muscular wall. (13-15mm)
- Pumps blood into the systemic circulation via the aorta.



Activity: using diagram 1 as a guide draw a flow chart that shows the correct flow of blood from the vena cava to the aorta. Make sure you include all the heart valves in the sequence

Electrical Activity:

Many cardiac fibres have the capability to self excite but this especially true of the fibres of the conduction system.

The heart requires a specific sequence of electrical activity to ensure appropriate pumping. The cardiac conduction system is a made up of specialised conduction tissue that has inherent properties of;

- automaticity.
- rhythmicity.
- conductivity.
- excitability.

Question: Give a short definition of each of the above terms.

Conduction system:

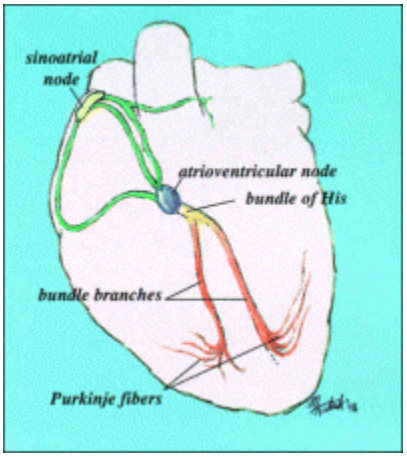
Is made up of the following structures that are arranged in order of their dominance. That is the system is designed so that if one part breaks another can take over. The SA node is the overall controller of the system, but if for some reason it fails the next structure down the list the AV node will take over.

Consists of;

- Sinoatrial (SA) node.
- Atrioventricular (AV) node.
- Bundle of His.
- Right and left bundle branches.
- Purkinje system.

SA Node;

- Situated at the junction of superior vena cava and the right atrium.
- Contains approx. 1.5 cm of conducting tissue.
- Fibres of SA node continuous with atrial fibres so that any action potential developed in the node spreads immediately to the atria.
- Strongest and fastest of all pacemakers.
- Discharges 60-100 times per minute.



AV node;

- Situated in the right posterior portion of the inter-atrial septum near the base of the tricuspid valve and adjacent to the opening of the coronary sinus.
- Is continuous with the bundle of HIS.
- Is specially designed to slow conduction
- Delays conduction of impulses by 0.08-0.12 seconds to allow for ventricular filling.
- Can discharge at 40-60 times per minute.
- Allows only one way conduction so only forward conduction from atria to ventricles can occur.

Bundle of His;

- Extremely rapid conduction of impulses.
- Composed of a thick bundle of fibres that runs down the right side of the intraventricular septum and then divides into the right and left bundle branches at the muscular portion of the septum.

- Right consists of one branch.
- Left consists of one long thin branch anteriorly and one short thick branch posteriorly.
- Continuous with purkinje system.

Purkinje system;

- Extremely rapid conduction of impulses.
- Transports impulse subendocardially into the ventricles.
- Can discharge at 20-40 times a minute.

Question: If for some reason the S.A. node is unable to generate an electrical impulse the A.V. node takes over as the dominant pacemaker of the heart. What is this type of rhythm called and what would be the resulting approximate heart rate.

Nervous Control

Both sympathetic and para-sympathetic nerves supply the heart.

Sympathetic Nerves;

Distributed to all parts of the heart in particular the ventricles.

Stimulation causes;

- Increased rate of sinus nodal discharge.
- Increases rate of conduction.
- Increases excitability.
- Increases force of contraction.

Para-sympathetic nerves;

Vagus nerve.

Stimulation causes;

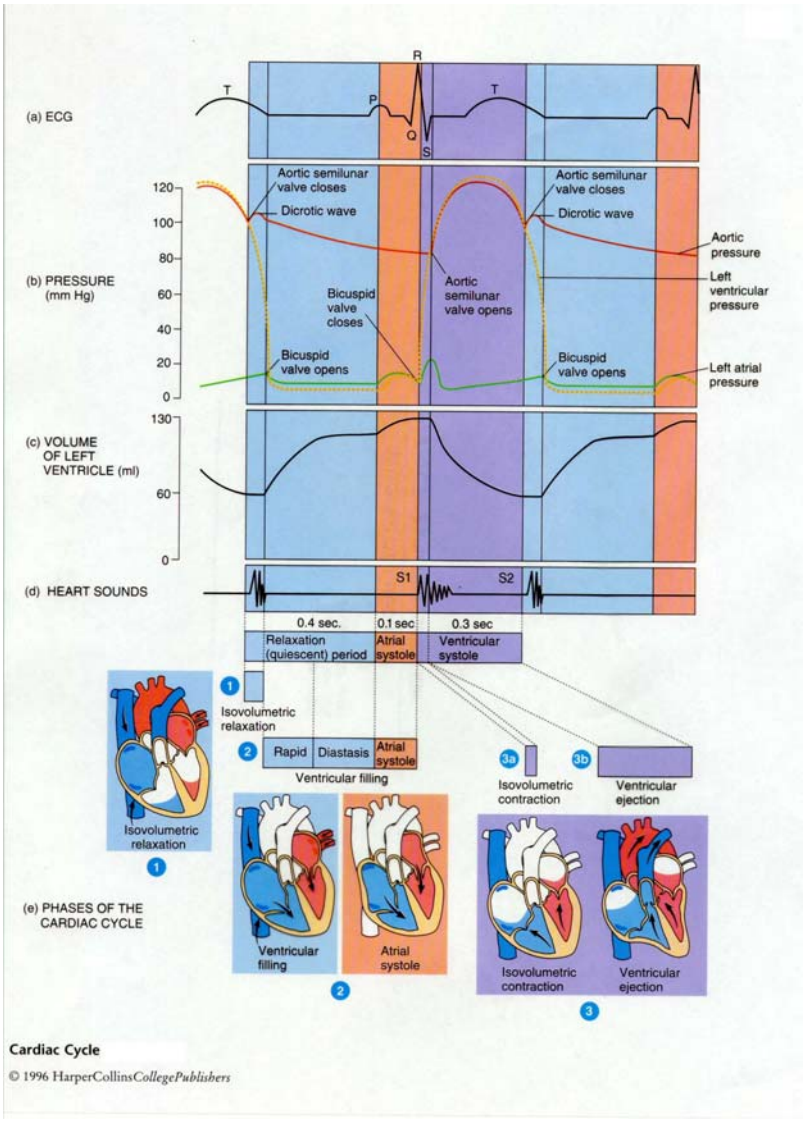
- acetycholine released.
- Decreases rate of sinus node discharge.
- Decreases excitability of AV fibres leading to slowing of transmission of impulses through the AV junction.
- Bradycardia and complete heart block can eventuate.

Question: I'm sure you have seen a patient have a vasa-vagul. With the previous reading in mind outline why the patient would display the classical signs?

The Cardiac Cycle.

Is the time period from the beginning of one heartbeat to the beginning of the next.

Involves both mechanical and electrical events. An electrical event, depolarisation leads to a mechanical event systole. While electrical recovery or repolarisation is accompanied by mechanical relaxation or diastole. An understanding of the cardiac cycle will allow you to better understand effects of drugs and pathophysiology of heart disease.



Events:

1] Atrial contraction;

- Is preceded on ECG by P-wave that signals atrial depolarisation is occurring throughout the P-R interval.
- Atrial contraction forces most of its contents into the ventricles with approx. 30% of left ventricular end diastolic volume being comprised of blood ejected during atrial systole.

2] Isovolumic Ventricular Contraction;

- Occurs immediately after QRS complex on ECG.
- Ventricular pressure rises rapidly with the mitral valve closing when pressure in the ventricle exceeds atrial pressure. Aortic valve is also closed during this time as ventricular pressure rises to overcome aortic pressure.
- In this phase the heart consumes up to 75% of its oxygen

Did you know? Since we know that 75% of the hearts oxygen is consumed in this phase many treatments are aimed at reducing this. As the degree of oxygen consumed is in relation to the pressure the ventricle has to overcome to empty into the aorta, treatments are aimed at this pressure. You know this pressure as Blood pressure, so to reduce the work of the heart patients are given tablets to reduce their blood pressure.

3] Rapid Ventricular Ejection;

- Ventricular muscle contraction continues until the aortic valve opens when aortic pressure is exceeded at approx. 80 mm/Hg.
- Ventricular pressure continues to rise until a maximum of approx. 120 mm/Hg.
- Two thirds or more of the ventricular volume is ejected.
- The left atrium is relaxed at this time and gradually filling with blood returning from the pulmonary circulation.
- Ventricular repolarisation as indicated by the T-wave begins.

4] Reduced Ventricular Ejection;

- ventricular muscle continues to contract but less vigorously with a corresponding decrease in ejection
- Atrial volume and pressure continue to rise.

- Ventricular repolarisation is usually complete by this time as indicated by the end of the T-wave.

5] Protodiastole;

- Ventricular muscle relaxation begins.
- A momentary back flow of blood as aortic pressure once again exceeds ventricular pressure facilitates aortic valve closure.

6] Isovolumic Ventricular Relaxation;

- All valves closed.
- No change in ventricular volume.

7] Rapid Ventricular Filling;

- Mitral valves opens as atrial pressure exceeds ventricular pressure.
- Blood flows passively into ventricle as it continues to relax and reach its maximum diastolic size.

8] Late Diastole;

- Blood from pulmonary circulation flows passively into the ventricle.
- Ventricular volume and pressure start to rise.
- Coronary artery flow is at its maximal.

Question: When patients go into atrial fibrillation, invariably their heart rate rises and their blood pressure drops, with the previous reading in mind how can you explain this?

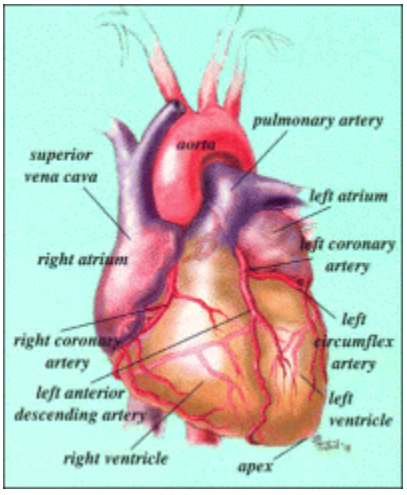
Question. What are the factors that affect venous return?

Definitions:

Preload; the tension exerted on the cardiac muscle at the end of diastole. In the normal heart can be measured as the left ventricular end diastolic pressure. Right Ventricular preload is indicated by measurement of JVP or CVP.

Afterload; is seen to be the force opposing left ventricular ejection.

Coronary Circulation: The Coronary Arteries.



As you read through this take particular note of the areas supplied by the particular coronary arteries as this can give you information as to why particular complications arise when one of the arteries become blocked as in acute MI. When we move on to ECG analysis you will learn to be able to identify which artery is blocked by looking at the 12 lead ECG. For example if the patient has right coronary artery disease and we know that the RCA supplies 90 % of the populations AV node then heart blocks and bradycardias can be anticipated if the RCA is blocked.

There are two coronary arteries that arise in the aorta at the sinus of valsava.

- Right Coronary artery, RCA.
- Left Coronary Artery, also known as the left main; has two important branches.
    - Left Anterior Descending, LAD.
    - Left Circumflex Artery, LCX.

The arteries transverse the epicardial layer of the heart with numerous branches leaving to distribute blood throughout the myocardium.

<u>Right Coronary Artery;</u> The RCA supplies

- Right atrium.
- Right ventricle.
- A portion of the inferior and posterior surface of the left ventricle.

- AV node and bundle of his in 90 % of hearts.
- SA node in 55% of hearts.

Left Main Coronary Artery;

* Approx. 1.5-2 cm in length and branches into the LAD and LCX arteries.

Left Anterior Descending Artery; the LAD supplies;

- Left and right ventricular myocardium.
- Most of the intraventricular septum.
- Ascending portion supplies posterior left ventricle.
- Bundle branches

Left circumflex artery; The LCX supplies;

- parts of the left atrium and lateral left ventricle.
- SA node in 45% of hearts.
- AV node in 10% of cases.
- Posterior left ventricle.

Question: A patient suffering a myocardial infarction involving the left circumflex artery is most likely to display what types of arrhythmia's? Why?

Activity

Fill in the blanks in the table using the above information

	Muscle supplied	Conduction tissue supplied	Probable arrhythmia's if compromised
Right coronary artery		55% SA node, 90% of AV node	
Left circumflex	Left atrium and lateral wall of left ventricle		
Left anterior descending			Bundle branch blocks

Cardiac Valves

Function; maintain unidirectional blood flow through the heart.

AV valves;

- Between atria and ventricles, consist of tricuspid (three cusps) valve between right atrium and right ventricle and mitral (two cusps) between left atrium and left ventricle.
- Are attached to the ventricular wall via chordae tendineae that are attached to the papillary muscles.
- Open passively during diastole due to the decrease in pressure in the ventricle compared to the atria.
- Towards end of diastole the increase in pressure in the ventricles and decrease in blood flow from the atria cause valve closure.
- During systole the cusps are prevented from inverting into the atria because of the chordae tendineae. During systole the papillary muscles are contracted tightening the chordae tendineae and preventing back flow of blood into the atria.

Semilunar Valves;

- Pulmonary valve between right ventricle and pulmonary circulation.
- Aortic valve between left ventricle and systemic circulation.
- Both composed of three cup shaped cusps.
- Thicker, stronger and more fibrous than the AV valves.
- Open on systole close in late systole due to deceleration of blood flow and inversion of the pressure gradient between the outflow tract and the ventricle.
- When pressure in ventricles exceed pressure in the outflow tracts.
- Back flow into the ventricles is prevented during diastole because of the cusps fibrous strength, shape and close fit.

Valvular Disease;

- Stenosis: valves unable to fully open, thus decreasing forward blood flow.
- Insufficiency/Regurgitation; valves unable to completely close, thus permitting backward blood flow.

Did you know?: Once you know which valve is affected and whether it is regurgitant or stenotic you can work out why certain symptoms are occurring. For example if a patient has stenosis of the mitral valve which means it is unable to open properly, then the flow of blood into the left ventricle will be reduced. As the LV pumps blood to the rest of the body, then you would expect the patient's blood pressure to be reduced and consequently their heart rate to be increased.
Also since blood cant travel into the left ventricle properly, it will build up in the areas behind the LV such as the LA and the lungs. As this collection of blood increase's, the individual will experience congestion in the lungs leading them to be short of breath or at times subject to pulmonary oedema.

References;

- Gavaghan; M. Cardiac anatomy and physiology: a review. *AORN journal. 67(4):800-828, april 1998.* 0001-2092
- Mohrman, D.E., Heller, L.J. 2007 Cardiovascular Physiology, 6th Edition
- Woods,S.L., Sivarajan Froelicher,E.S., Jean Halpenny,C., Underhill,S.L., 1999. Cardiac Nursing. J.B. Lippincott. Philadelphia, USA.
- Wright,J.E., Shelton, B.K. 1993 Desk Reference for Critical Care Nursing. Jones and Bartlett Pub. Boston USA.