Laboratory 7 - Electrocardiography and The Diving Reflex

INTRODUCTION

EKG:

The electrocardiogram (ECG or EKG) is the standard clinical tool used to measure the electrical activity of the heart. Data obtained from an EKG provide a graphical representation of the rate, rhythm and pattern of electrical signals produced by the movement of action potentials through cardiac myocytes. Recall that in a cell at rest, the inside of the cell has a negative charge with respect to the outside. That charge reverses when an excitable tissue such as a cardiac muscle cell depolarizes during an action potential. If one group of cardiac myocytes is depolarized, positive inside and negative outside, while another group is at rest, negative inside and positive outside, we have perfect conditions to generate an electrical current. If these oppositely charged areas are then connected by some sort of a conductor an electrical current will flow. In our bodies the extracellular fluid acts as a conductor allowing current to flow around the heart. Electrodes placed at strategic locations can detect that current. By attaching the electrodes to a galvanometer, tracings can be recorded that give us information about the magnitude and direction of the currents. Furthermore, by placing the positive and negative electrodes at different locations on the body the EKG will give different "views" of the electrical activity. Each unique positioning of the electrodes is referred to as a **lead**. By placing the electrodes in different positions a total of 12 standard leads can be obtained, six limb leads and 6 chest leads, giving 12 unique views of the electrical activity of the heart with each from a slightly different perspective.

In this lab, we will look only at Standard Lead I.

The deflections (waves) produced by the EKG are named using letters of the alphabet: the **P wave** represents depolarization (current change) of the right and left atrial muscles (atrial depolarization), the **QRS complex** represents depolarization of ventricular muscle. The **T wave** represents repolarization of both ventricles. Therefore, both the P wave and the components of the QRS complex are **depolarization waves** while the T wave is generated when the ventricles recover from depolarization and is known as a **repolarization wave**. Because the current measured by the EKG has both direction and magnitude, the signals can be interpreted as vectors. This resulting vector can be used to "map" the electrical activity of the heart.

Pulse Pressure:

Each time the heart beats blood is pumped into the aorta and on to the rest of the arterial system. At the aorta and in the other large arteries this pulse pressure is large with a typical 40 mmHg difference between the maximum and the minimum pressures. As the pressure wave moves through the arterial system the magnitude of the wave falls. When blood reaches the capillaries there are almost no fluctuations in the pressure and blood flow is continuous. The 2 main factors that affect the magnitude of the pulse pressure are stroke volume of the heart and compliance (stretchability) of the blood vessel walls. An increase in stroke volume will increase the pulse pressure whereas and increase in compliance will decrease the pulse pressure.

The pressure pulses move through the arteries much faster than the blood. In a normal aorta pulses travel at a speed of 3-5 m/sec, 7-10 m/sec in the large arteries and 15-35 m/sec in the small arteries. The primary factor that influences the velocity of the pressure pulses is the compliance of the vessel, in general the greater the compliance the slower the velocity. Even in the aorta where the velocity of the pressure pulse is slowest it is 15 or more times faster than the velocity of the blood.

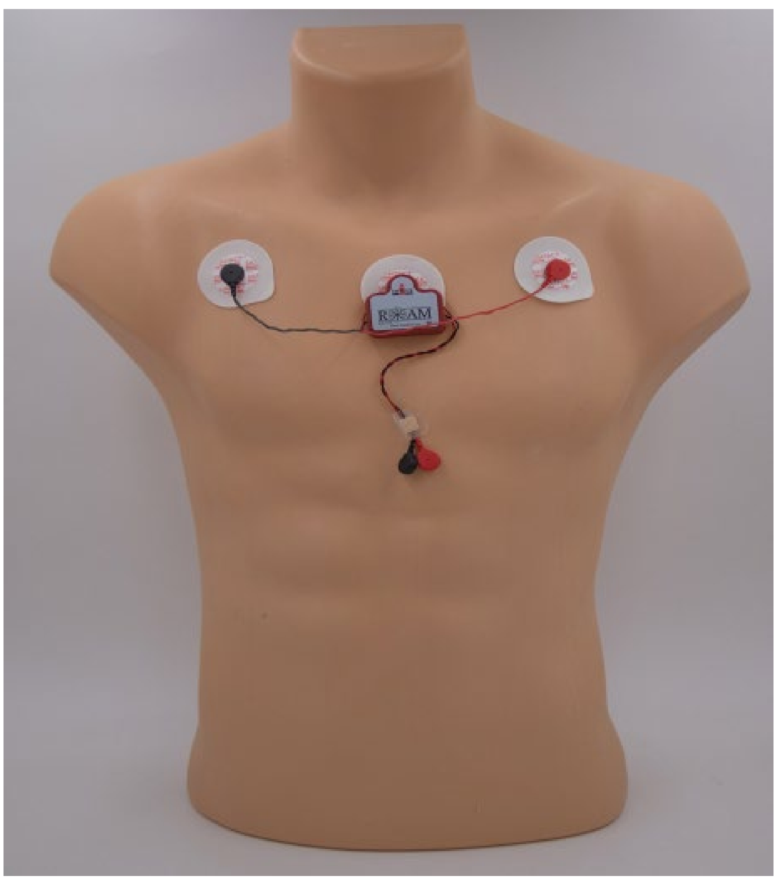
If we take the integral of the pulse pressure we can see the changes in pressure over time. An interesting feature of the integrated curve is the small valley observed as the pressure begins to drop. This valley is called the dicrotic notch or incisura and is generated by the closing of the semilunar valves at the onset of ventricular diastole. By examining the pressure wave we can obtain information regarding the mechanical activity of the heart. The time from the beginning of the pulse wave to the dicrotic notch represents ventricular systole and the time from the dicrotic notch to the beginning of the next pressure wave represents ventricular diastole. The amplitude (height) of the pulse wave is influenced by the strength of contraction (changes in stroke volume) and by vasoconstriction (changes in arterial compliance).

PROCEDURE

In this exercise we will use the I-works data recording system to perform the EKG under control and various experimental conditions. We will also utilize the plethysmograph to measure the pulse wave of the blood in the finger. By comparing the EKG with the pulse wave we can investigate the time delay that occurs between the electrical events in the heart and mechanical events in the circulatory system. The figure below is an example of what the data output should look like if everything is set up properly.

The top panel is a typical EKG reading from Lead II, the center panel shows the pulse wave from the plethysmograph and the bottom panel is the mathematical integral of the pulse wave which demonstrates the dichrotic notch. To record these data setup the I-works data recording system to use the ECG-Circulation-ROAM settings.


iWorx TA-ROAM
ROAM
ROAM Wireless
HV Stimulator
A1
A2
A3
A4
A5
A6
A7
PT
iWire
1
2
LV Stim
S1
S2


ROAM

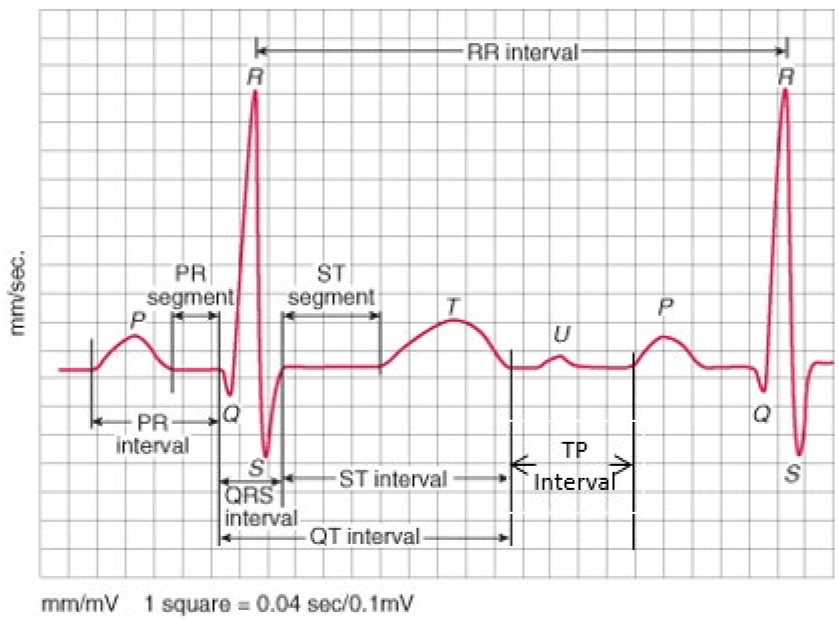
Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of the subject's middle finger or thumb, and wrap the Velcro strap around the end of the finger to attach the unit firmly in place.

Instruct the subject to sit or lay quietly with their hands in their lap. If the subject moves, the ECG trace will be disrupted.

Exercise 1

Hit record and take a sample of the subjects EKG. Stop the recording and proceed (you will want to record the following data in the table for exercise 2:

This picture may help:



1. Measure the PR interval. It is measured from the beginning of the P wave to the beginning of the QRS complex (Since many EKG tracings will not have a Q wave it is called the PR interval but it should be measured to the beginning of the QRS complex. If the subject has a Q wave it is to the beginning of the Q wave, if not it is to the beginning of the R wave). This is the time it takes an action potential to travel from the SA node to the ventricles and represents the delay between atrial and ventricular contraction. The PR interval should be between 0.12 and 0.2 seconds. A PR interval of greater than 0.2 seconds could indicate dysfunction of the AV node. or thyroid issues. hyperthyroidism. (Note: for this and all measurements find a representative segment of the data and average the measured value for three consecutive beats)
2. Measure the QRS interval. It should be between 0.05 and 0.10 seconds**.** A prolonged QRS interval could be due to impaired conduction through the ventricles as would happen with a

bundle branch block. It could also be due to an abnormal conduction path as would occur with an ectopic focus in the ventricles.

5. Measure the QT interval. This interval reflects the time from the beginning of ventricular depolarization to the end of ventricular repolarization. Normal QT intervals range from 0.2 to 0.4 seconds. An abnormally long QT interval can be indicative of a condition known as Long QT Syndrome which is potentially life threatening. Since the QT interval is affected by rate, cardiologists typically compute the Acorrected@ QT interval (QTc). QTc is calculated by dividing the measured QT interval by the square root of the R-R interval (QTc = QT interval/R-$R^{1/2}$) Normal QTc's are less than 0.44 seconds. In addition to Long QT syndrome, other causes of a long QT interval include: coronary artery disease, hypocalcemia, hypothyroidism, hypothermia, certain prescription drugs and cardiomyopathy. For a description of cardiomyopathy go to (http://www.americanheart.org/presenter.jhtml?identifier=4468).
6. Measure the T-P interval. This is from the end of the T wave to the beginning of the next P wave. This is the time when the heart is at rest and is being perfused with blood.
7. Compare the measured intervals for the EKG at rest, after exercise and during the dive reflex. Record you data in the table below. Which intervals changed the most during the various exercises? why?
8. Measure the R-Pulse interval by placing one cursor on the tip of the R wave of the EKG in the top panel and the other at the beginning of the pulse wave in the second panel.
9. Measure the length of systole by placing the first cursor at the beginning of a pulse wave and the second cursor at the center of the dicrotic notch (this measurement is made on the integrated pulse wave.
10. Measure the length of diastole by placing one cursor in the middle of the dicrotic notch and the other at the beginning of the next pulse wave (again use the integrated pulse wave).
11. Record your data in the tables below and then answer the questions.

Exercise 2. The EKG and Pulse in a Subject at Rest and After Exercise
(Note: for ease in analyzing your data place markers at the beginning of and within each exercise so that you can easily find the data. For example a simple marker “Resting” could be used to identify this exercise)

1. Record your resting data that you collected above in the table below.
2. Have the subject ride the exercise bike for a few minutes. The exercise should be vigorous enough to raise the heart rate to around 150 beats/minute. Monitor heart rate to ensure that the exercise is sufficiently intense.
3. Have the subject sit or lie down again record EKG and pulse for one minute
4. Have the subject lie quietly for 5 minutes and then record for another minute.
5. Record the values for the items in the table below using your tracings.

Effects of exercise on EKG and Pulse waves			
	Rest	After exercise	5 min after exercise
Heart Rate			
PR Interval			
QRS Interval			
QT Interval			
QTc Interval			
TP Interval			
R-Pulse Interval			
Pulse height			
Length of systole			
Length of diastole			

Exercise 3. The effect of Cold and Heat on the Pulse and EKG

1. With the subject lying quietly on the bench start the recording and obtain a consistent control reading
2. Place a bag containing a mixture of ice and water on the subject’s left forearm (same limb as the plethysmograph is attached to) and continue to record for 2 minutes (mark the start of the cold application).
3. Remove the cold bag and continue to record for another 2 minutes (mark the point of removal).
4. Move the plethysmograph to the middle finger of the subject’s right hand. **This is important, because if you do steps 5 and 6 on the same arm, your data will not work well, because there is likely some residual effects from the ice. Be sure to do steps 5 and 6 on the other (right) arm.
5. Take a sample recording to make sure the tracings are good and get some baseline data, reposition the plethysmograph as needed.
6. Repeat the steps in exercise 2, but this time apply a hot water bag to the right forearm of the subject.
7. Record the values for the items in the table below using your tracings.

Effects of Hot and Cold Water on Pulse Waves and Heart Rate			
	Control	Cold	Heat
Heart Rate			
R-Pulse Interval			
Pulse Height			

Exercise 4. The Effect of Deep Breathing on the EKG

1. With the subject lying quietly on the table record a control EKG.
2. Have the subject inhale and exhale deeply and slowly for several breaths. Mark the beginning of each inhalation and each exhalation.
3. Record the values for the items in the table below using your tracings.

Effect of Deep Breathing on EKG and Heart Rate			
	Control	Inhaling	Exhaling
Heart Rate			
QT interval			
TP interval			
PR interval			

Exercise 5. The Dive Reflex

The application of cold water to the face while holding one's breath (apnea) initiates the dive reflex. The dive reflex results in a decrease in heart rate (bradycardia). Breathing stops in terrestrial vertebrates when they dive due to simulation of sensory receptors located in the nasal passages and pharynx. These sensory receptors respond to cold and submersion and reflexively cause apnea. In mammals, stimulation of these facial receptors also causes a marked bradycardia, possibly through stimulation of parasympathetic fibers. This exercise investigates the temperature dependent nature of the bradycardia. Subjects voluntarily hold their breath and immerse their face into cold water, actually cold water is an understatement, while their heart rate is monitored.

1. Fill a tub with room temperature water.
2. Fill another tube with cold water, around 5^{o} C, and record temperature
3. Record a 20 second resting EKG and then have subject immerse his face into room temperature water.
4. Record as long as subject is able to hold breath.
5. Repeat with the cold water bath.
6. As a control have the subject hold his breath as long as possible without immersing their head in water.
7. Hints for minimizing data error
   Subject should not talk or laugh during any of the recording segments
   Subject should be sitting at the bench so that he can easily place his face in the water
   Subject should relax and hold as still as possible during recording segments

Subject should remain immersed for 20-30 seconds or longer – the longer the better (try to stay immersed the for the same time in each trial)

8. Record the values for the items in the table below using your tracings.

Effect of Diving on Heart Rate				
	Control	Breath Holding	Room temp	5° C
Heart Rate				
QT interval				
TP interval				
PR interval				
Time*				

* How long did they hold their breath?

DATA ANALYSIS

As mentioned above the EKG provides information about rate, rhythm and patterns of electrical activity of the heart. We will perform a basic evaluation of your EKG tracing. In the image below the various waves, intervals and segments are shown.

Lab questions are on the following 2 pages…

Lab Questions:

1. List the ranges for the intervals in the table in Exercise 1 (don't worry about finding normal values for R-pulse, TP or pulse height as the first two depend on heart rate and pulse height depends on the lead). For the intervals that do have normal ranges, provide a brief discussion of what is happening during each interval. (It might not be a bad idea to run your interval lengths by a TA before you leave)
2. Below are several conditions that would cause the PR interval to be longer than normal. Pick 2 and describe their mechanisms. *(1st Degree Heart Block, Hypothyroidism, and Hypokalemia)*
3. Below are two conditions that would cause the QRS interval to be longer than normal. Describe their mechanisms. (*Bundle Branch Block and Ventricular Ectopic Focus.)*
4. Below are several conditions that would cause the QT interval to be longer than normal. Pick 2 and describe their mechanisms. (*Coronary Artery disease, hypocalcemia, hypothermia, Long QT syndrome, cardiomyopathy.)*

5. Which interval changed the most after exercise? Is this what you would have expected? Explain the mechanism for the changed interval. (Check with the TA to make sure your results gave you the right interval)
6. How did the "strength and rate" of systole change with exercise? Explain the mechanism for the observed result.
7. What effect did cold water have on pulse height? How do you explain these results?
8. What effect did hot water have on pulse height? How do you explain these results?
9. What changes were observed in heart rate when the subject inhaled? exhaled? Explain these results.
10. What had a greater impact on heart rate, holding one's breath or holding one's breath while submersed in cold water?
11. Did the temperature of the water have an impact on the results of the diving reflex?
12. Explain the mechanism for the changes in heart rate during the dive response.

Abnormal EKG Questions:

Exercise 6. Abnormal EKG

[CLICK HERE] to open a web page that will go through pathological EKG tracings. After you go through this tutorial look at the tracings we have provided below and try to find the BEST matches.

Simply memorizing what the pathology is and its correlating EKG reading on THIS sheet **WILL NOT** prepare you for a similar section on the lab quiz or course exam. We highly recommend really taking your time to learn about what each pathology is, and **WHY** it creates it's correlated tracing. Tracings may not fit what you learn exactly, but there is a BEST tracing to go with each listed condition.

If you understand the mechanisms of each of the pathologies, you should have no problems recognizing their respective tracings. This will help a lot in cases where tracings look quite different and in cases where we put a tracing you have never seen before on an exam.

Questions

1. The tracings we hope for you to learn are illustrated on the next pages. Place the correct number for the tracing in the blank associated with each condition listed below

A. Normal sinus rhythm ________________

B. First degree AV block ________________

C. Second degree AV block – or - Mobitz Type I heart block ________________

D. Second degree AV block – or - Mobitz Type II heart block ________________

E. Third degree AV block ________________

F. Sinus tachycardia ________________

G. Sinus bradycardia ________________

H. Paroxysmal supraventricular tachycardia ________________

I. Atrial fibrillation ________________

J. Atrial flutter ________________

K. Premature atrial contraction (PAC) ________________

L. Premature ventricular contraction (PVC) ________________

M. Ventricular fibrillation ________________

1.

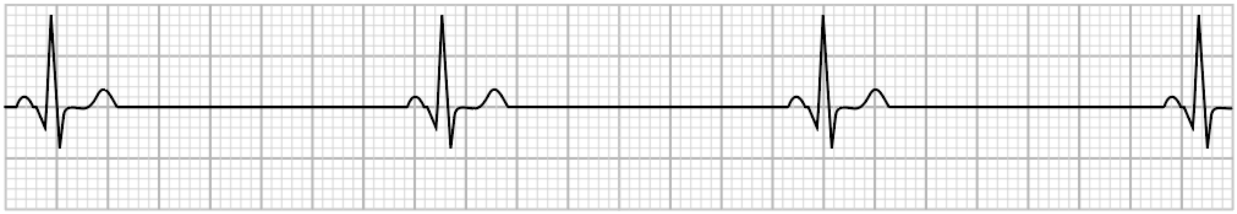
2.

3.

4.

5.

6.



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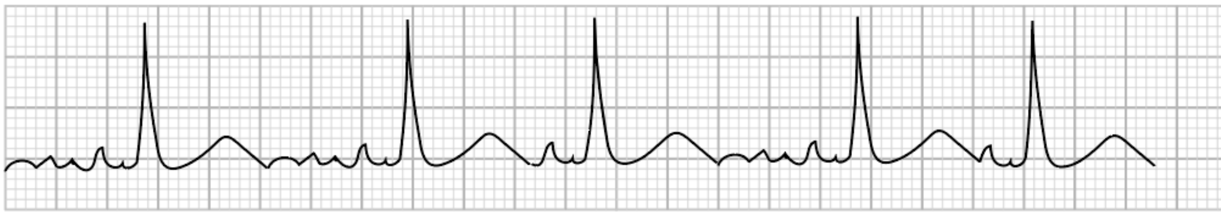

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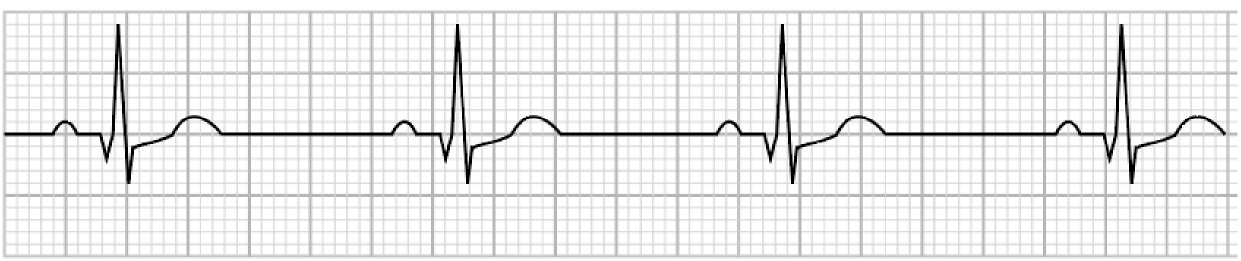

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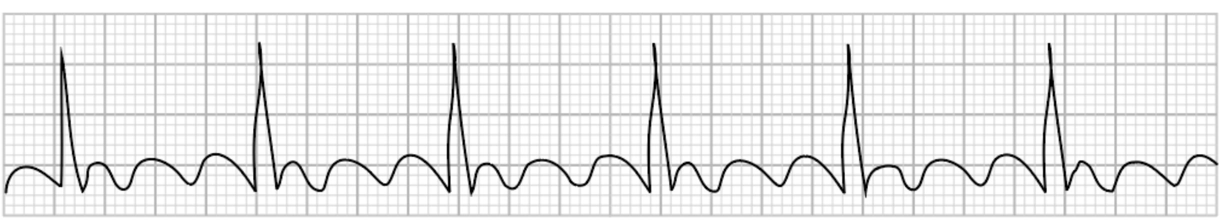

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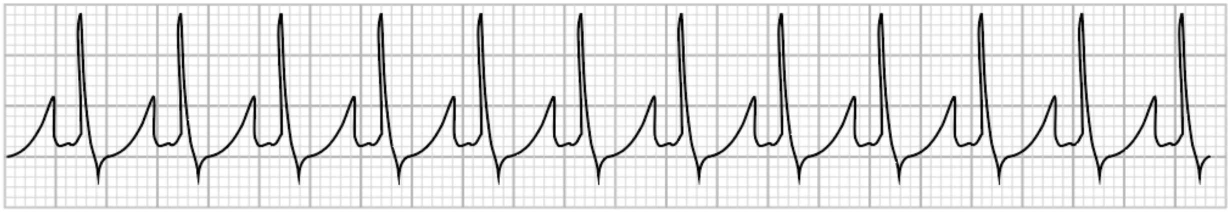

12.

13.