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Electrophysiology

Chapter Synopsis

This chapter covers the electrical events that control the cardiac cycle and introduces the EKG waves and complexes and the conduction system. Many practice examples enhance learning. Two 75-minute classes should be enough to cover this chapter.

Chapter Outline

I. Introduction
II. Depolarization and Repolarization
III. The Action Potential
    A. Phase 4
    B. Phase 0
    C. Phases 1 and 2
    D. Phase 3
IV. Refractory Periods
    A. Absolute
    B. Relative
    C. Supernormal period
V. EKG Waves and Complexes
    A. P wave
    B. T_a wave
    C. QRS complex
    D. T wave
    E. U wave
VI. Waves and Complexes Identification Practice
VII. QRS Nomenclature

A. Q wave
B. R wave
C. S complex
D. QS wave

VIII. QRS Nomenclature Practice

IX. Cardiac Conduction System
A. Conduction Pathway

X. Cardiac Cells
A. Automaticity
B. Conductivity
C. Excitability
D. Contractility

XI. Inherent (Escape) Rates of the Pacemaker Cells

XII. Conduction Variations

XIII. EKG Paper

XIV. Intervals
A. PR interval
B. QRS interval
C. QT interval

XV. Intervals Practice

XVI. Chapter 2 Notes—To Sum It All Up…

XVII. Practice Quiz

XVIII. Putting It All Together—Critical Thinking Exercises

Chapter Objectives

Upon completion of this chapter, the student will be able to:

- Define the terms *polarized, depolarization,* and *repolarization* and relate them to contraction and relaxation.
- Describe and label the phases of the action potential.
- Define *transmembrane potential.*
- Draw and explain the P wave, QRS complex, T wave, and U wave.

- Explain where the PR and ST segments are located.
- Define the *absolute* and *relative refractory periods* and the implications of each.
- Be able to label, on a rhythm strip, all the waves and complexes.
- Explain the delineations of EKG paper.
- On a rhythm strip, determine if the PR, QRS, and QT intervals are normal or abnormal.
- Name the waves in a variety of QRS complexes.
- Define *pacemaker.*
- List the different pacemakers of the heart and their inherent rates.
- Track the cardiac impulse from the sinus node through the conduction system.
- Define the four characteristics of cardiac cells.
- Describe the difference between *escape* and *usurpation.*
- Define *arrhythmia.*
- Tell what happens:

  When the sinus node fails.

  When the sinus node and atria both fail.

  When the sinus node, atria, and AV node all fail.

Frequently Asked Questions (FAQs) by Students

- How can the T_a wave be happening at the same time as the QRS complex?

  Suggested answer: The T_a wave and the QRS complex represent events happening simultaneously in different chambers of the heart. These events do not cancel each other out—they occur simultaneously. Because ventricular depolarization generates a large amount of electrical current, it "swallows up" the T_a wave that occurs at the same time.

- How can a rhythm have no P wave?

  Suggested answer: Some rhythms originate in different parts of the conduction system and do not depolarize the atria, thus no P wave is written. There are many rhythms that have no P waves.

- Why is a purely negative QRS complex called a QS wave? Why not just Q or just S instead of both?

  Suggested answer: A Q wave is a negative wave that precedes an R wave. An S wave is a negative wave that follows an R wave (just as in the alphabet). If there is no R wave to go by, the negative wave can't really be called a Q or an S, so a compromise is made and it is called QS.

- What happens if all the pacemakers fail?

  Suggested answer: If all the pacemakers fail, there are no waves or complexes at all on the EKG printout. There is only a flat line to indicate the complete lack of electrical current in the heart. The patient in this case has no pulse, is not breathing, and is clinically dead.

- Can a pacemaker stop for a while and then "wake up" again?

  Suggested answer: Absolutely. In fact, that is a frequent occurrence. Hopefully, one of the other pacemakers will keep things going until the faster pacemaker resumes control.

- Do patients feel it when a different pacemaker takes over?

  Suggested answer: Patients do not feel the change in pacemakers per se. What they feel, if anything, is a change in heart rate, either faster or slower. Some patients report feeling palpitations when a lower pacemaker usurps the predominant pacemaker at a very rapid heart rate. And some patients feel a big thump when there has been a long pause and an escape beat kicks in. This change in heart rate, either faster or slower, can cause symptoms of low cardiac output.

Suggested Class Activities

- Hand out practice sheets with different QRS configurations and have the students name the waves.
- Have students get into small groups and practice labeling the waves and complexes of various rhythm strips. The students who are catching on more quickly can help the slower ones.

- Have an electrophysiology bee. Line students up against the wall. Ask each student a question about electrophysiology. Students answering incorrectly sit down. The last one standing is the winner.
- If you have access to a rhythm simulator, show the students a sinus rhythm with a rate between 60 and 100. Then show a junctional rhythm with a rate between 40 and 60. Finally, switch to a ventricular rhythm with a rate between 20 and 40. This is a good way for the students to see what the slower heart rates caused by each lower pacemaker look like.
- Have the students label a diagram of the conduction system.
- Have the students track the heart's current from the sinus node through the conduction system to the ventricle.
- Have four students stand in front of the class. Assign each one to be a pacemaker of the heart. Have a small ball on the table in front of them. Ask them to demonstrate what happens in sinus rhythm. The sinus student should pick up a ball and hand it to the atrium, who hands it to the AV node/junction, who hands it to the ventricle. The student representing the ventricle jumps up and down to indicate depolarization.
- Now ask them to demonstrate what happens when the sinus node fails. Typically, the next pacemaker in line to replace the failing sinus node is the AV junction. The sinus node and atrium students should do nothing. The AV node/junction student should pick up the ball and hand it to the ventricle, who then jumps up and down to represent depolarization.
- You can make up more scenarios like this. It is undeniably corny, but it gets the students participating and makes them laugh (especially the poor student who represents the ventricle by jumping up and down).

Critical Thinking Exercises

Utilize the following scenarios or make up your own to get the students thinking about electrophysiology.

- Mr. Miller's heart monitor alarmed, showing his rhythm was a flat line. Have the students explain what is happening—or not happening—electrically and mechanically. Will he have a pulse?

Suggested answer: Mr. Miller's flat line tells us that nothing is happening electrically in his heart. There is no depolarization or repolarization. And if there is no depol/repol, there can be no mechanical response. The heart can't pump if it has not been depolarized first. There will be no pulse.

- Mrs. Tucker has a rhythm that has no P waves. Have the students explain what this means in terms of atrial depol/repol and the phases of diastole.

  Suggested answer: If there is no P wave, there is no atrial depolarization and therefore no atrial contraction/atrial kick. **This does not mean there is no blood flow from atrium to ventricle**. Blood flow from atrium to ventricle will still occur passively as usual in the first phases of diastole. There will just not be the atrial kick to squeeze the last 15–30% of the blood into the ventricle.

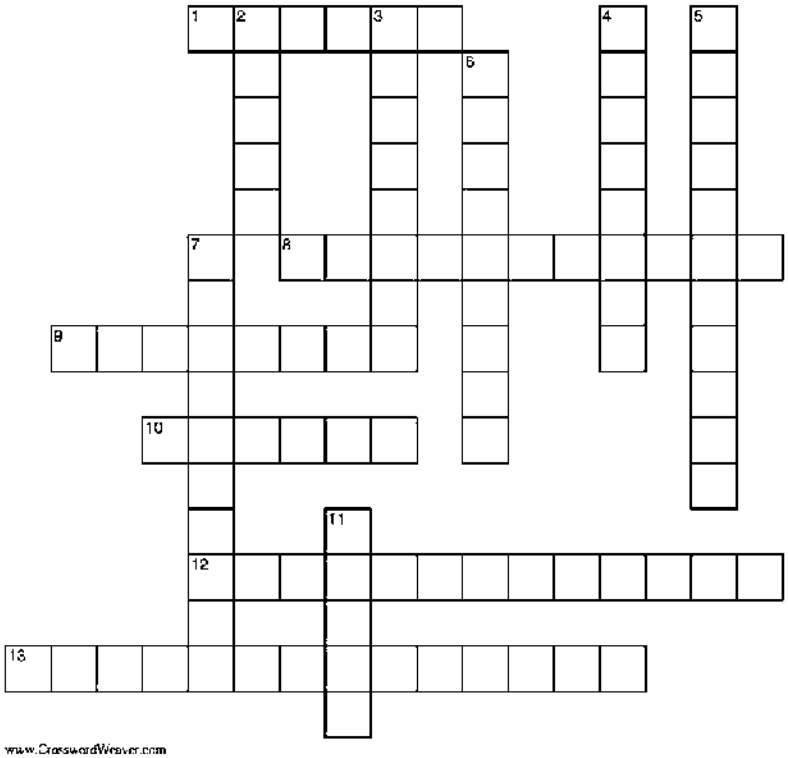
- Mr. Tart has a PR interval that has changed from 0.12 seconds to 0.24 seconds after starting a new medication. Have the students tell what this PR interval change means physiologically. Are the intervals normal or abnormal?

  Suggested answer: The increased PR interval means it takes the impulse longer to reach the ventricle than before the medication was started. The new PR interval is abnormally prolonged.

Crossword Puzzle

The crossword puzzle below can be used as a take-home or in-class test, or just given out as practice.

Chapter 2



ACROSS

1 A safety mechanism in which a lower pacemaker fires at its slower inherent rate when a faster pacemaker has failed
8 QRS complex is the spikey wave that represents _____ depolarization.
9 The flat line between the EKG waves and complexes
10 P wave is the small rounded wave that represents _____ depolarization.
12 The ability of a cell to contract and do work
13 The change in electrical current from negative to positive

DOWN

2 The _____ node is the normal pacemaker of the heart.
3 The fibers at the end of the conduction system that propel the impulses at blazing speed throughout the ventricles
4 The refractory period in which no electrical stimulus will result in depolarization
5 Depolarization should result in muscle _____ .
6 Measurements of time between the PQRS-T waves and complexes
7 Transmembrane potential is the _____ charge at the cell membrane.
11 The AV node is the part of the conduction system that slows impulse conduction to allow the _____ to dump blood into the ventricles.

Chapter 2

Solution: