**Study Material: Pathophysiology and Classification of Cardiac Arrhythmia**

**Learning Outcomes**

After studying this topic, you should be able to:

1. Explain the normal electrophysiology of the heart.
2. Describe the ionic basis of action potentials.
3. Understand how electrical impulses are generated and conducted.
4. Identify the mechanisms and causes of arrhythmias.
5. Understand the effect of abnormal conduction and refractory periods.
6. Classify arrhythmias based on heart rate and site of origin.
7. Know the drug classification used in treatment.

**Normal Physiology of Cardiac Rhythm**

**🔹 Electrical Excitability of Myocytes**

* Cardiac myocytes are capable of generating and conducting action potentials.
* Resting membrane potential:
  + Ventricular myocytes: **-90 mV**
  + SA Node: **-40 mV**
* **Na⁺/K⁺ ATPase Pump**:
  + Keeps Na⁺ outside, K⁺ inside the cell in resting state.

**Depolarization and Impulse Propagation**

* Action Potential starts with **Na⁺ influx** (depolarization).
* Signal spreads across myocardium → causes synchronized contraction.

**⚡ Electrophysiology: Ion Movements**

| **Ion** | **Concentration Gradient** | **Role** |
| --- | --- | --- |
| Na⁺ | Higher outside the cell | Influx causes depolarization |
| K⁺ | Higher inside the cell | Efflux causes repolarization |
| Ca²⁺ | Higher outside the cell | Influx during plateau phase |

* The membrane potential is maintained by:
  + Ion selective channels
  + Active pumps (Na⁺/K⁺ ATPase)
  + Ion exchangers

**Cardiac Action Potential Phases**

| **Phase** | **Description** | **Key Events** | **ECG Correlate** |
| --- | --- | --- | --- |
| **0** | Rapid Depolarization | Fast Na⁺ channels open | Start of QRS complex |
| **1** | Initial Repolarization | Na⁺ channels close, transient outward K⁺ & Cl⁻ current | R/S wave |
| **2** | Plateau | Influx of Ca²⁺ balances K⁺ efflux | ST segment |
| **3** | Repolarization | K⁺ efflux dominates | T wave |
| **4** | Resting Phase | Ion gradients restored | Diastole |

**Cardiac Arrhythmia: Definition & Mechanism**

**Definition**

An arrhythmia is an abnormality in heart rhythm involving rate, regularity, origin, or conduction of impulses.

**Mechanisms of Arrhythmias**

* Abnormal impulse generation
* Abnormal impulse conduction
* Re-entry circuits
* Triggered activity (EADs and DADs)

**Pathophysiological Effects**

* Inadequate cardiac output due to inefficient contractions.
* Can lead to syncope, stroke, or sudden cardiac death in severe cases.

**Clinical Features (Symptoms)**

* Palpitations
* Dizziness
* Syncope (fainting)
* Fatigue
* Chest discomfort
* Shortness of breath

**Clinical Classification of Arrhythmias**

**1. Based on Heart Rate**

| **Type** | **Heart Rate** |
| --- | --- |
| **Bradycardia** | < 60 beats per minute |
| **Tachycardia** | > 100 beats per minute |

**2. Based on Rhythm**

| **Type** | **Description** |
| --- | --- |
| **Regular** | Consistent intervals |
| **Irregular** | Variable intervals |

**3. Based on Site of Origin**

| **Type** | **Description** |
| --- | --- |
| **Supraventricular** | Originates above the ventricles (e.g., SA/AV node) |
| **Ventricular** | Originates in the ventricles |

**4. Based on ECG Complexes**

| **Type** | **Description** |
| --- | --- |
| **Narrow QRS** | Impulses via normal conduction system |
| **Broad QRS** | Abnormal or delayed ventricular conduction |

**Classification of Antiarrhythmic Drugs**

Based on **Vaughan-Williams classification**:

| **Class** | **Drug Mechanism** |
| --- | --- |
| I | Na⁺ channel blockers (e.g., Lidocaine) |
| II | β-blockers (e.g., Propranolol) |
| III | K⁺ channel blockers (e.g., Amiodarone) |
| IV | Ca²⁺ channel blockers (e.g., Verapamil) |
| Others | Digoxin, Adenosine, etc. |

**Reflection Questions**

1. What are the ionic changes in each phase of cardiac action potential?
2. How does the site of arrhythmia origin affect ECG morphology?

**Summary**

* Cardiac rhythm is tightly regulated by ion flux and conduction pathways.
* Arrhythmias can arise due to disturbed generation or propagation of impulses.
* Classification helps determine diagnosis and treatment strategies.