بسم الله الرحمن الرحيم

Pharmacology lecture
Cardiac arrhythmias: Types, mechanisms and drugs

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Introduction

Conducting system vs contractile tissue of the heart

Conducting System:

SA node, AV node, Purkinj fibers

Contractile tissues

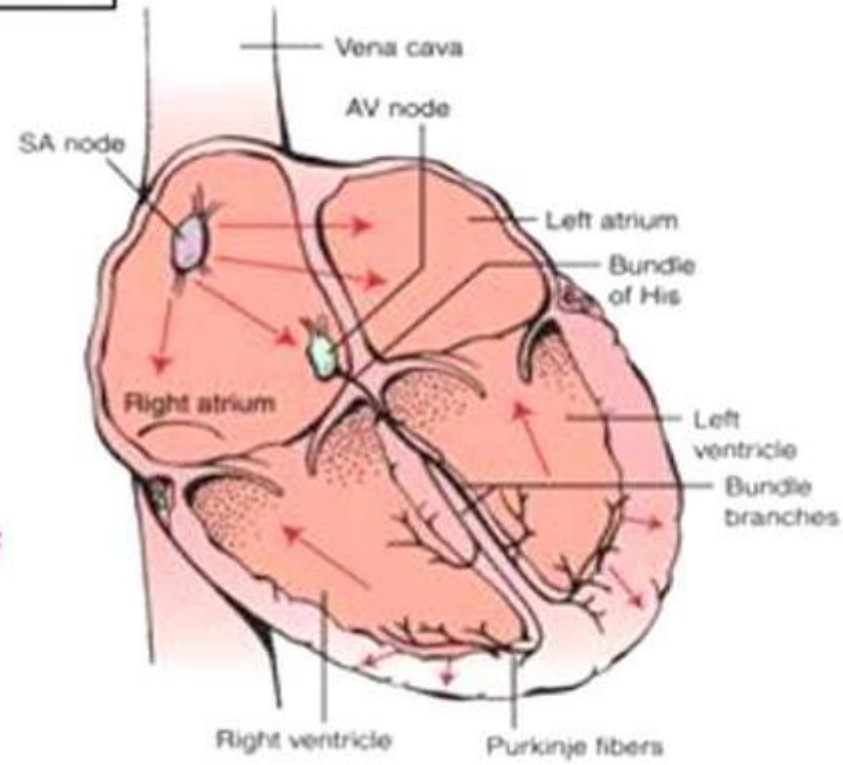
Atrial & Ventricular muscles

Impulse Propagation:

- SA node → AV-node → Bundle of His → Purkinje fibers → ventricle.

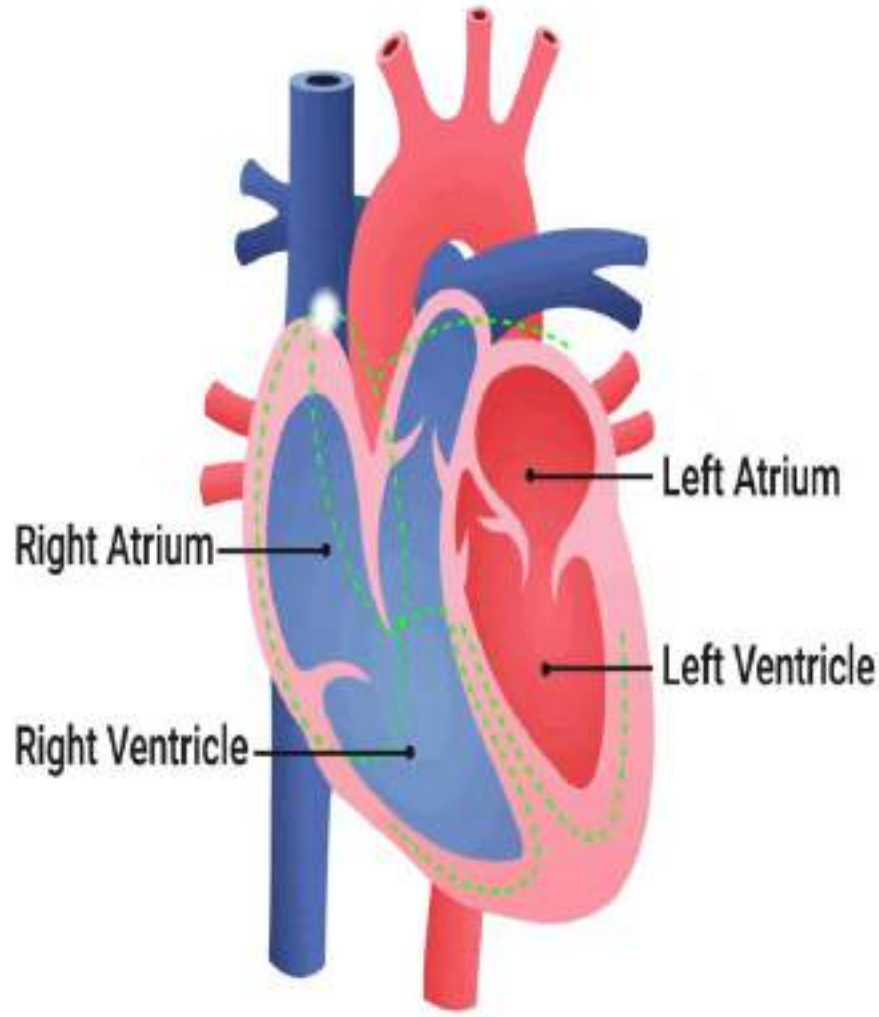
- SA node is the initial pacemaker.

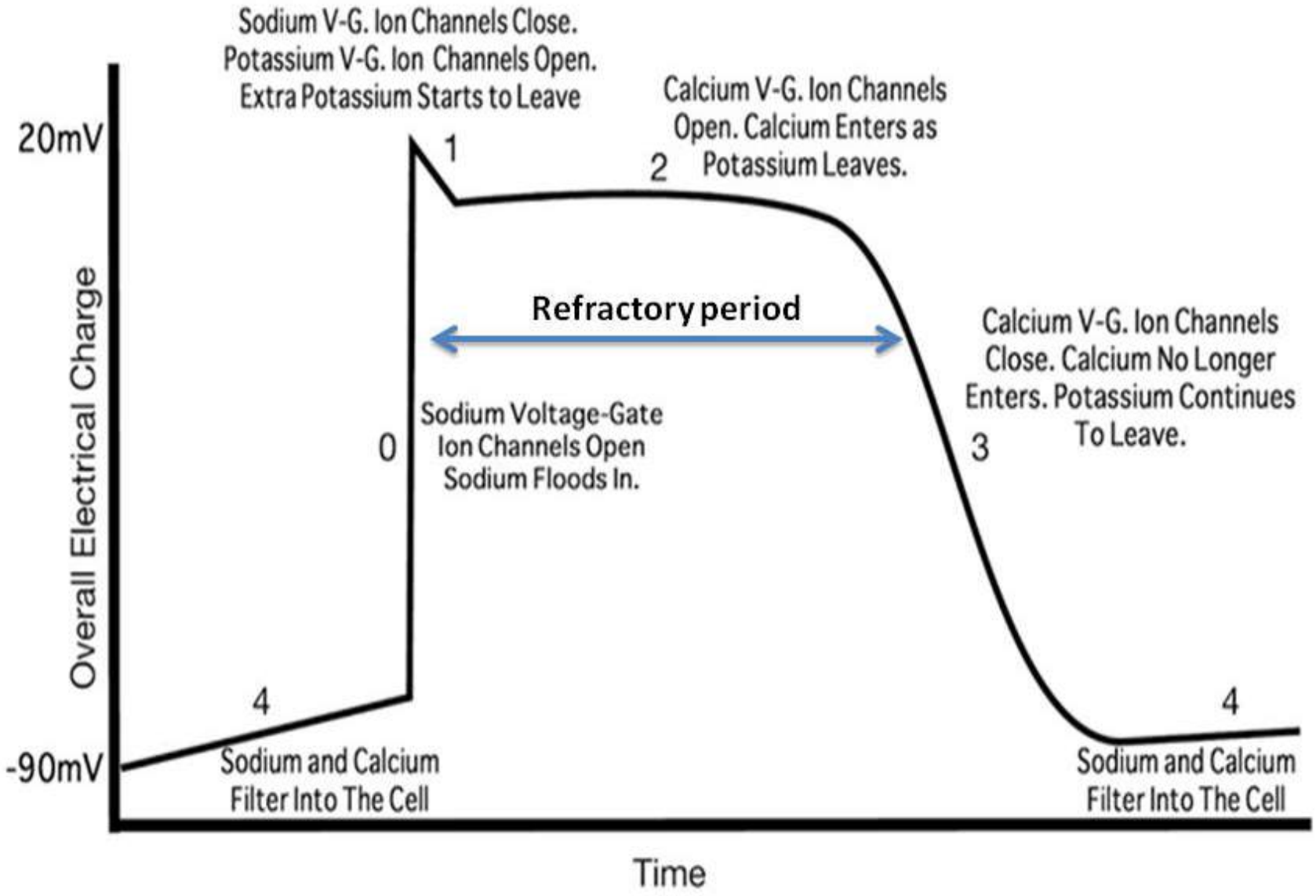
- To understand the action of antiarrhythmics, electrophysiology of the heart must be reviewed.



Cardiac properties in relation to the phases of action potential

1. **Automaticity:** is represented by spontaneous depolarization (phase 4).
2. **Conduction**: represented by phase 0 (maximal rate of depolarization or Vmax).
3. **Effective refractory period** (ERP): is represented by phase 1, 2, 3 until the membrane is repolarized to -60 mV. It is represented by the width of depolarization. During ERP, cardiac cells cannot respond to a new conducted stimulus.




Sodium V-G. Ion Channels Close.
Potassium V-G. Ion Channels Open.
Extra Potassium Starts to Leave
1
Calcium V-G. Ion Channels
Open. Calcium Enters as
2 Potassium Leaves.
20mV
Overall Electrical Charge
Refractory period
Calcium V-G. Ion Channels
Close. Calcium No Longer
Enters. Potassium Continues
To Leave.
3
0
Sodium Voltage-Gate
Ion Channels Open
Sodium Floods In.
4
4
-90mV
Sodium and Calcium
Filter Into The Cell
Sodium and Calcium
Filter Into The Cell
Time

Cardiac arrhythmias

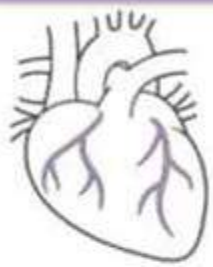
- **Arrhythmias**: are **abnormal heartbeat** (abnormalities in **rate**, **rhythm** or **both**) due to abnormality in **automaticity** (ectopic beats), abnormality in **conductivity** (reentry) or abnormality in **both**.
- **In arrhythmias,** cardiac depolarization deviate from normal in one or more aspects: abnormality in the **site of origin of the impulse**, its **rate** or **regularity**, or its **conduction.**
- **Anti-arrhythmic drugs** are those drugs that **suppress** the abnormality of cardiac rhythm by **blocking specific ion channels** (Na^+, Ca^{++} and K^+) or by **altering autonomic functions**.

Causes of Arrhythmia

1. Electrolyte disturbance as hypokalemia and hypocalcemia.
2. Myocardial ischemia, hypoxia and Myocardial Infarction.
3. Acidosis or alkalosis.
4. Excess catecholamine.
5. Hypoglycemia.
6. Overstretching of cardiac fibers.
7. Drug toxicity (as digitalis and anti-arrhythmic drugs).

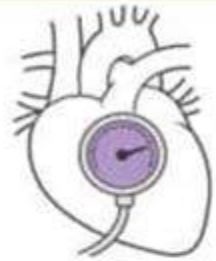
Arrhythmia occurs in **25 % of patients** with **digitalis** therapy and in **70 %** of the cases of acute **myocardial infarction** (MI).

Risk factors for cardiac arrythmias and cardiac arrest



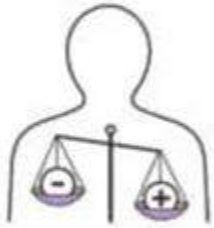
Coronary artery disease

Heart valve disorders

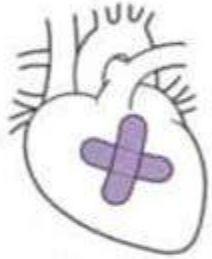


High blood pressure

Alcohol abuse



Electrolyte imbalances in the blood



Trauma or injury to the heart due to surgery, infection, or previous heart attack

Electrocution

Cardiomyopathy and changes in the heart muscle

Drugs and medication

Genetic disorders

Congestive heart failure

Congenital heart defects

Types of cardiac arrhythmias

A. Supraventricular (atrial) arrhythmia:

1. Sinus tachycardia (pulse more than 100 beats / min.).
2. Sinus bradycardia (pulse less than 60 beats / min.)
3. **Supraventricular tachycardia,**
4. **Atrial flutter (regular fast)**
5. **Atrial fibrillation (irregular fast)**

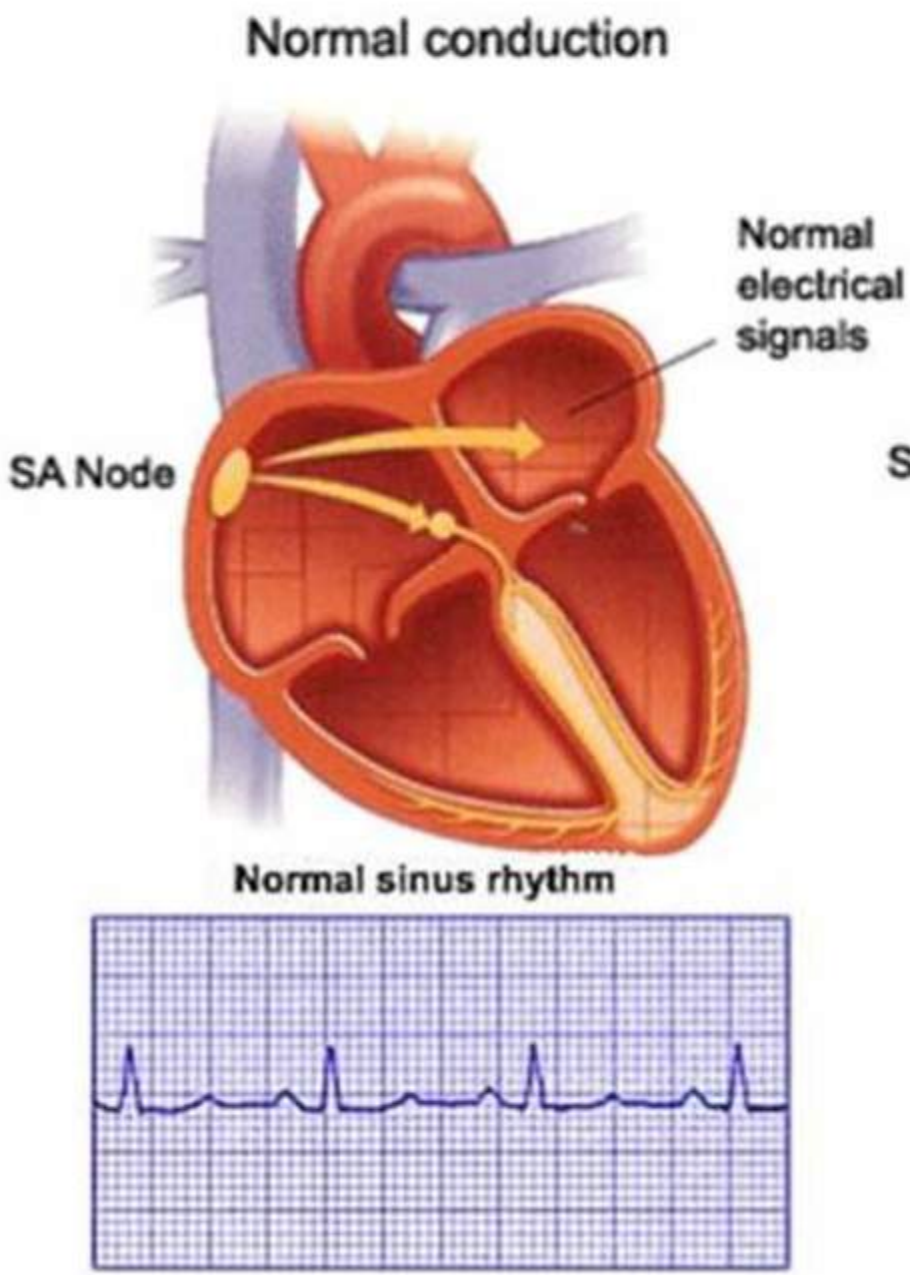
B. Ventricular arrhythmia:

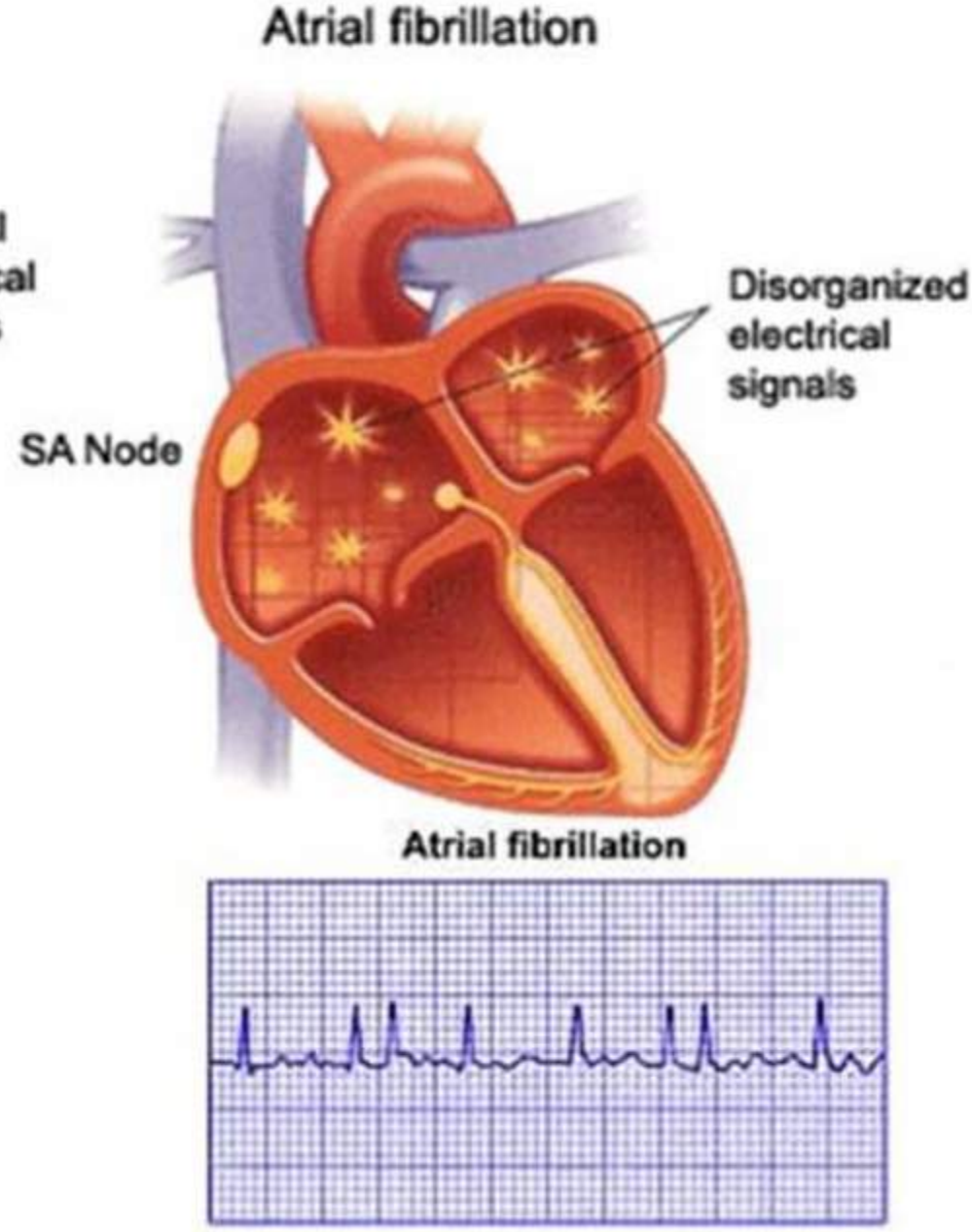
i. **Ectopic beats: ventricular premature contractions.**
ii. **Ventricular tachycardia (monomorphic or poly morphic).**
iii. **Ventricular fibrillation.**
iv. **Torsade de pointes and asystole**

C. Partial and complete AV conduction block

N.B. Ventricular arrhythmias are life-threatening.
N.B. Underlined disorders are due ectopic rhythms (away from SA node)

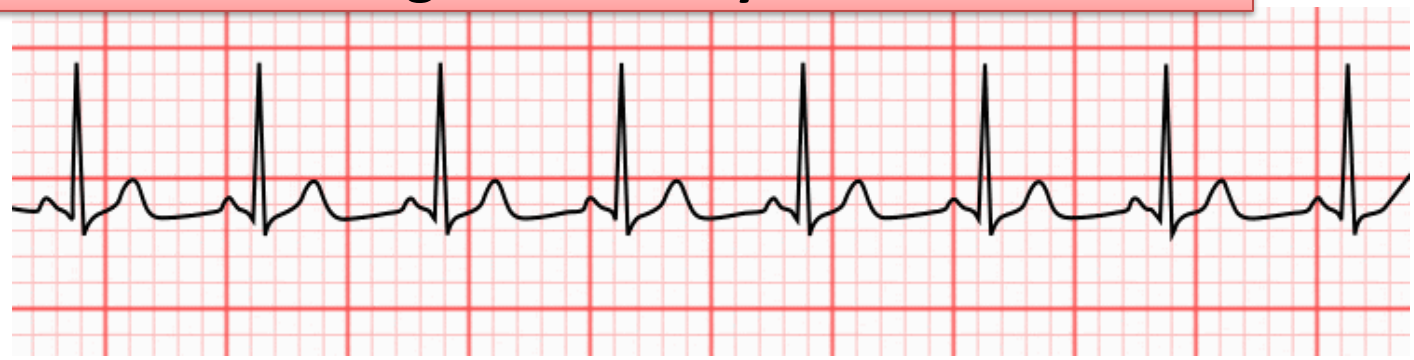
ECG for diagnosis of arrythmias



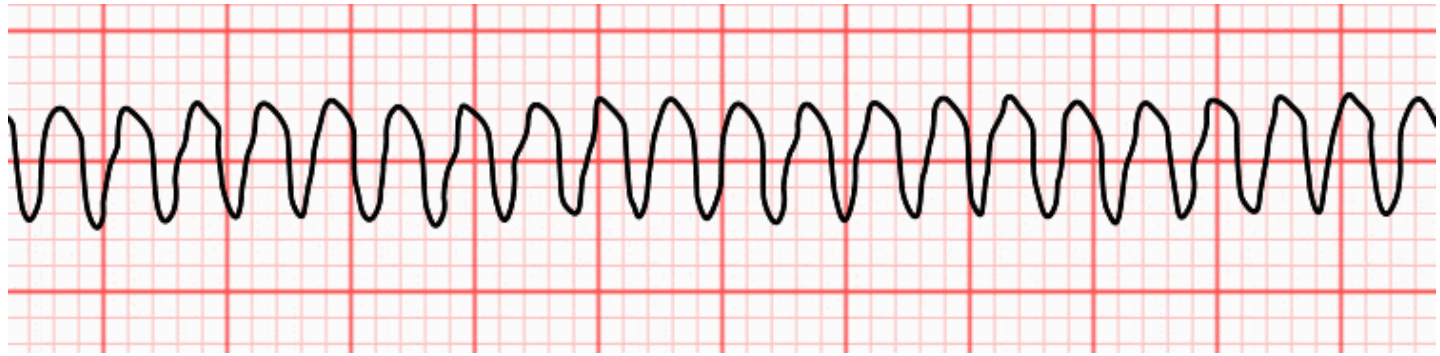


ECG for diagnosis of arrythmias

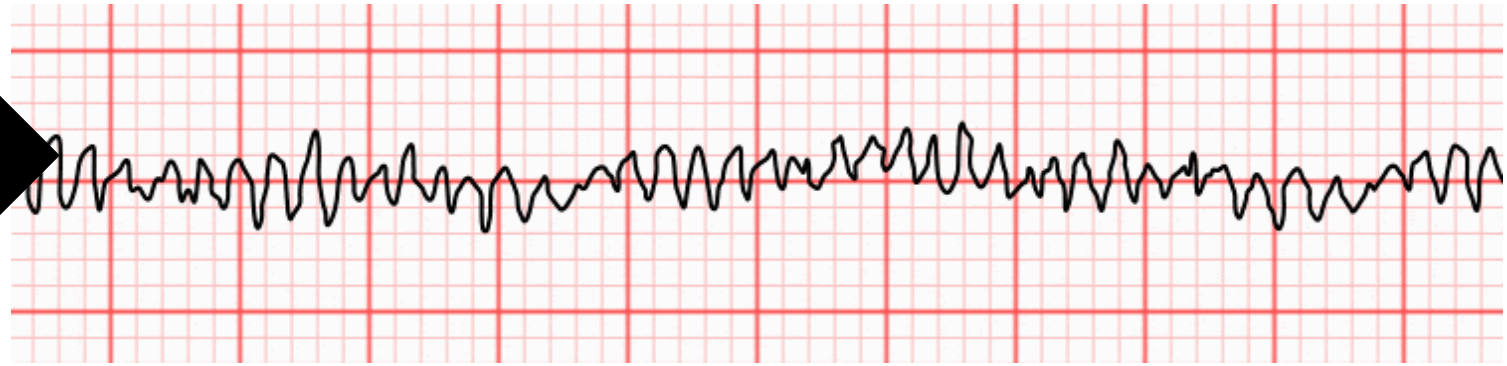
Normal sinus rhythm



VTC



VF



VTC= ventricular tachycardia; VF= ventricular fibrillation

Goals of treatment of arrhythmias

- To **terminate** already present arrhythmias.
- To **prevent recurrence** of arrhythmias in susceptible patients.
- To **protect ventricles** against arrhythmias during atrial arrhythmias.
- To **Restore** normal sinus rhythms.

Management of cardiac arrhythmias

1- Non-pharmacological approach:

Pacemaker *or catheter ablation,* ***Implantable cardioverter/ defibrillator*** , Direct current (**DC**) electrical shock (***cardioversion***).

2-Avoid and treat predisposing factors

3- Using Antiarrhythmic drug therapy.

Class	Mechanism	Example
I	Na channel blockers Membrane Stabilisers	Lignocaine
II	Beta Blockers	Metoprolol
III	K channel blockers	Amiodarone
IV	Ca channel blockers	Verapamil
Other	Digoxin. Adenosine. MgSO4. Atropine	

Classification of anti-arrhythmic drugs

Type IA
- Disopyramide
- Procainamide
- Quinidine

Type IB
- Lidocaine
- Mexiletine

Type IC
- Flecainide
- Propafenone

Type II
- Beta blockers (e.g., propranolol)

Type III
- Amiodarone
- Bretylium
- Dofetilide
- Ibutilide
- Sotalol

Type IV
- Nondihydropyridine calcium channel antagonists (verapamil and diltiazem)

SUBGROUP 1A

1-Quinidine

- It is obtained from cinchona plant

1. **Blocking Na+ channels:**
   1. Suppresses ectopic activity and terminating abnormal automaticity.
   2. Depresses conduction velocity and terminate abnormal reentry.
2. **Blocking K+ channels:** Prolonging AP duration and ERP in ventricular muscles (i.e. increases refractoriness).
3. **Additional autonomic actions:**
   A. atropine like action.
   B. Alpha adrenergic blocking action.

Class I Antiarrhythmic Drug Effects

On the Ventricular Action Potential:

On the ECG:

↑QRS & ↑QT ↓QT ↑↑QRS

Therapeutic uses:

1- Supraventricular arrhythmias:

- Treatment of paroxysmal Supraventricular tachycardia.
- Prevention of recurrence of atrial fibrillation and atrial flutter after **cardioversion** (direct current will restore sinus rhythm) and quinidine will prevent the recurrence of ectopic pacemakers.
- **Co-medications** with quinidine in case of AF (**Anti-coagulants** + **verapamil** or **Beta blockers**).

2-Ventricular arrhythmias:

- Treatment of ventricular extrasystole.
- Prevention of recurrence of paroxysmal ventricular tachycardia after cardioversion.

N.B. **I.V. quinidine** may be used in the treatment of ***acute malaria***.

Treatment of atrial fibrillations (AF)

A) Before treatment of AF, we need to:

1. Decrease A-V nodal conduction by β-blockers or Ca^{++} channel blockers (verapamil) or digoxin to protect the ventricles from receiving rapid atrial impulses.
2. **Use of anticoagulant drugs** as AF is usually associated with stagnation of blood with thrombosis in the atrium.

B) Termination of AF: **cardioversion will restore sinus rhythm.**

C) ***Prevention of recurrence of AF:*** After correction of atrial fibrillation, the sinus rhythm is maintained using quinidine, amiodarone or dofetilide.

N.B. Quinidine ***Increase the level serum digoxin and enhance its toxicity***: due to its displacement from tissue binding and by decreasing its renal excretion. **This is a dangerous drug-drug interaction.**

Adverse effects of quinidine

i- Cardiac toxicity

1- Quinidine syncope (Torsade de pointes):

due to blocking of K^+ channels → polymorphic ventricular tachycardia.

2- Embolism with old standing AF: intra-arterial thrombi → which become dislodged on conversion to sinus rhythm by quinidine.

3- Decrease the myocardial contraction: worsen **heart failure.**

4- Hypotension especially with I.V. quinidine.

5- A-V nodal block and S-A nodal block in high doses.

ii- Atropine- like actions.....

iii- Extracardiac toxicity

1. ***GIT toxicity***: nausea, vomiting & **diarrhea** (occurs in 20%).
2. ***Cinchonism:*** **tinnitus**, **hearing loss**, **blurring of vision**, headache, diplopia, **photophobia**, confusion and **psychosis**.
3. ***Hypersensitivity reactions***: fever, thrombocytopenia and hepatic dysfunction.

2- Disopiramide: like quinidine but it has **no α blocking activity** but **more anti-cholinergic activity** .

3-Procainamide

- It lacks the atropine-like action of quinidine.
- It is better tolerated than quinidine when given I.V. infusion in emergencies.
- It causes more hypotension due to blocking of α-adrenergic receptors and autonomic ganglia.
- It **does not cause Cinchonism.**
- It is metabolized in the liver by acetylation.
- It may cause SLE-like syndrome in 30 % of patients.
- SLE-like syndrome is dose-dependent.
- SLE-like syndrome is more common in slow acetylators

SUBGROUP 1 B

1-Lidocaine

-It is a local anesthetic and anti-arrhythmic drug.

Mechanism : blocking of activated and inactivated Na+ -channels.

- ✓ It decreases conduction velocity (terminate reentry).
- ✓ Highly effective in **arrhythmias of ischemia and digitalis toxicity**
- ✓ Ineffective against atrial flutter and atrial fibrillation.
- ✓ **Lidocaine is effective in ventricular arrhythmias only.**
- ➢ Therapeutic doses **do not affect contraction** or vascular resistance.
- ➢ Lidocaine is the least cardiotoxic & hypotensive anti-arrhythmic drug.

Pharmacokinetics:

1) It has an extensive first-pass metabolism in the liver, so it is used **only I.V**. for antiarrhythmic applications.
2) It crosses BBB producing CNS excitation.
3) It has rapid onset and short duration of action ($t_{½}$ is 2 h.), so suitable in emergent ventricular arrhythmia.

Therapeutic uses in arrythmia:

Lidocaine (I.V.) is used in ventricular arrhythmias caused by Myocardial infarction, Open heart surgery and Digitalis intoxication.

- **Adverse effects of lidocaine**

1. ***CNS stimulation:*** confusion, tremors, convulsion & then CNS depression.
2. **Hypersensitivity reactions**.
3. **Hypotension if given by large doses**.

2- Tocainide

- It is a **lidocaine analog**, but **used orally.**
- The major adverse effects are **tremor and nausea**.
- Rarely used (it caused fatal bone marrow aplasia & pulmonary fibrosis)

3- Mexiletine

- It is **like lidocaine** in actions and uses but given only ***orally***.
- May cause CNS symptoms (dizziness, light headedness and **tremors**) and GIT symptoms (nausea and **vomiting**).

4- Phenytoin

- It is antiepileptic and antiarrhythmic drug
- It **blocks** the inactivated **cardiac Na^+ channels.**
- It has a **depressant effect on the sympathetic centers** in CNS and is especially useful in arrhythmias related to **digitalis toxicity.**

SUBGROUP 1C

1-Flecainide 2-Propafenone 3- Moricizine

- They are the most potent antiarrhythmic drugs in blocking Na channels in all cardiac cells including anomalous pathway of Wolff Parkinson White Syndrome (WPWS).

Therapeutic uses: Severe life-threatening ventricular arrhythmia & WPWS.

Side effects:

1. They may aggravate preexisting arrhythmia or induce new one.
2. Increase the incidence of sudden death in patients taken drug than the placebo (non-taken).

Group 3 (K^+ CHANNEL BLOCKERS)

General characters:

1. They **prolong repolarization** and increase action potential duration due to blocking of K channel. They **Prolong Q-T interval in the ECG**.
2. They **block other channels** or **autonomic functions** except **dofetilide** which is a **pure potassium channel blocker**).

1- Amiodarone

Pharmacological effects:

- It **blocks K^+-channels, Na+-channels**, **Ca++ channels**, **beta and α-adrenergic receptors** causing:
- It prolongs the action potential **of atrium, ventricle & A-V node**.
- **Decrease in the conduction** of A-V node.
- **Reduction of both normal** and abnormal **automaticity.**
- Peripheral **vascular dilation** due to Ca^{++} and α-blocking activity.
- **It has Structural analog to thyroid hormone.**

Pharmacokinetics:

Used orally, has delayed onset and long duration; **t ½ (25-60 days).**

it is used in **high loading dose** (for 2 weeks) followed by low maintenance dose once/day.

Therapeutic uses: in both atrial and ventricular arrhythmias.

1. It is used to maintain sinus rhythm in patients with atrial fibrillation.
2. Treating ventricular fibrillation "if resists Lidocaine & cardioversion".
3. Recurrent unstable sustained ventricular tachycardia.

Side effects:

1. **Corneal microdeposits** (due to deposition of drug in cornea).
2. **Thyroid dysfunction**: hypothyroidism or hyperthyroidism.
3. Reversible **pulmonary fibrosis** which may be fatal.
4. **Cardiac toxicity**: bradycardia, A-V block, paradoxical ventricular arrhythmia (Torsade de pointes, but unusual), heart failure & hypotension.
5. **Hepatic injury.**
6. **Photosensitivity** due to deposition of the drug in the skin.

2- Dronedarone (non-toxic amiodarone)

- **Dronedarone** is a structural analog of amiodarone in which the iodine atoms have been removed.
- So, dronedarone is free of thyroid dysfunction or pulmonary toxicity.
- The drug has a **half-life of 24 hours.**
- Dronedarone absorption increases twofold to threefold when taken with food.
- Dronedarone is both a **substrate and an inhibitor of CY3A4 (drug interactions).**

3- Sotalol

- Sotalol is a non-selective beta-adrenergic blocker that prolongs the cardiac action potential due to K^+-channel blocking activity.
- It can be used in **atrial and ventricular arrhythmias.**
- Side effects as beta-blockers (**bradycardia**, **A-V block** and **heart failure**) and torsade de pointes only with high doses or in presence of **renal dysfunction**.

4- Dofetilide

- **it is a pure K^+-channel blocker,** used to maintain sinus rhythm after cardioversion correction of atrial flutter or fibrillation.
- The main side effect is the risk of torsade de pointes.

5- Ibutilide

It is a Class III antiarrhythmic agent available in **intravenous formulations**.
It is indicated for the **conversion of acute atrial flutter & recent onset atrial fibrillation to normal sinus rhythm .**

Group 5 (Miscellaneous antiarrhythmic drugs)

1- Magnesium sulfate

- I.V. Mg SO_4 is effective in:

1-Digitalis induced arrhythmias if hypomagnesemia is present.
2- Some cases of torsades de pointes and acute myocardial infarction even if serum Mg^{++} is normal.

2- Adenosine

- It is an endogenous purine nucleotide that binds to adenosine receptors type 1 (A1) which is G-protein coupled receptor causing **inhibition of cAMP-mediated Ca^{++} influx** in atrial and nodal tissues

Therapeutic uses:

1. Effective **only in atrial arrhythmia**, it is the ***drug of choice*** in treatment **of paroxysmal supraventricular tachycardia** (due to its short duration and less myocardial depression).
- It is used by ***bolus I.V.*** injection, it has very short duration of action ($t_{½}$ is less than 10 seconds) due to rapid metabolism. If it is given slowly, it will be metabolized before reaching the heart.

1. It is used to induce controlled hypotension during surgery.
2. It is used for diagnosis of coronary artery disease.

Side effects:

1. Flushing and chest pain in 20 %
2. Theophylline and caffeine block its receptors, so they decrease its effect

3- Digoxin

- It inhibits Na+/K+ ATPase. Used in treatment of heart failure.
- Used to protect ventricles from atrial fibrillations.

4- Ranolazine

- Anti-anginal drug.It is a a new agent in the control of AF.

5- Ivabradine

Ivabradine functions in a use-dependent fashion at the **SA node**, and lowering heart rate (bradycardic drug) without affecting inotropy or vascular resistance.

The adverse effects of ivabradine are related to symptomatic bradycardia.

Remember

- Atropine is the first line drug for treating bradycardia and AV block.
- Also, Administration of isoproterenol may facilitate both normal and depressed conduction in the A-V node and His-Purkinje system.
- However, Permanent pacing is the therapy of choice in patients with symptomatic atrioventricular (AV) block with bradycardia.


THANK
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