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AD-COR Program inovativ de formare in domeniul cardiologiei pediatrice
POSDRU/179/3.2/S/152012

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MODUL TEORETIC

Arrhythmias in postoperative paediatric cardiac critical care and care of patients with temporary pacemaker

Imputernicit: Prof. Dr. Tammam Youssef

Activitate prestata de I.R.C.C.S. POLICLINICO SAN DONATO – MILANO, ITALIA in baza contractului nr. 18/22144/29.07.2015

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Lecture II

Bucharest, October 22, 2015

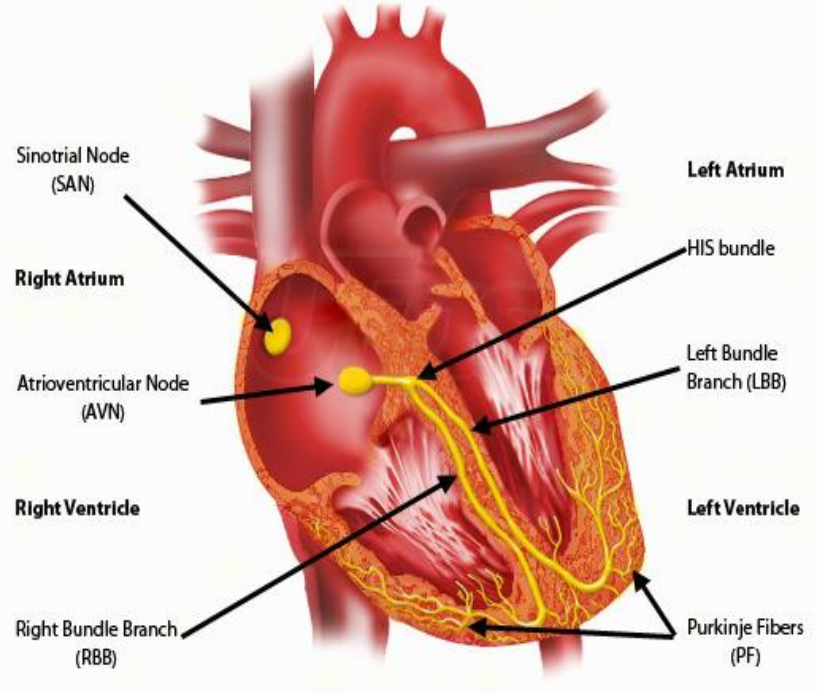
Matthias Angrés, MD, PhD
RobinAid Foundation
Hamburg / Germany

Let‘s continue with the next topic

Arrhythmias in postoperative paediatric cardiac critical care and care of patients with temporary pacemaker

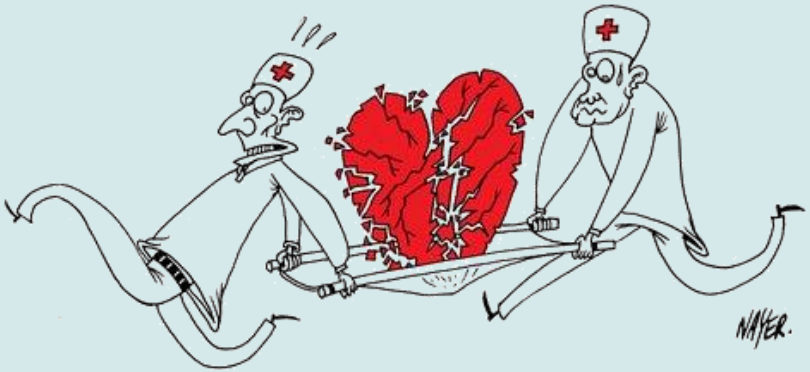
The cardiac conduction system

- The Sinoatrial (SA) node is the natural pacemaker of the heart
- The SA node releases electrical stimuli at a regular rate which is dictated by the needs of the body
- The electrical stimulus from the SA node eventually reaches the AV node by the internodal pathways
- After this the stimulus passes through the AV node and Bundle of His into the Bundle branches and Purkinje fibres



Arrhythmias in paediatric cardiac surgery

- Early postoperative arrhythmias are known complications in paediatric cardiac surgery
- **Incidence between 15 - 45 %**
- Transient and treatable in most cases
- Haemodynamically instable arrhythmias are **related to increased mortality**



Triggering factors

- Lower body weight (5 to 9 kg)
- Younger age (6 to18 months)
- Longer C.P.B.P. and aortic crossclamp times
- Use of deep hypothermia and circulatory arrest
- **Inflammatory response**
- Type of intervention

Triggering factors

- Residual lesions
- Postoperative cardiac dysfunction
- **Scar and sutures**
- Electrolyte disturbances
- Catecholamine stimulation
- **Pain, anxiety**
- Stress response

Most important arrhythmias

Annals of Pediatric Cardiology
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Ann Pediatr Cardiol. 2014 Jan-Apr; 7(1): 19–24.
doi: 10.4103/0974-2069.126543
PMCID: PMC3959055

Anticipation and management of junctional ectopic tachycardia in postoperative cardiac surgery: Single center experience with high incidence

Osama Abdelaziz and Salem Deraz[1]

Early post. operative arrhythmia	Number of patients	% of whole cohort (194)
JET	53	27
Junctional rhythm	14	7.2
Transient heart block	12	6.2
Permanent heart block	3	1.5
JET alternating with heart block	5	2.5
SVT	5	2.5
Atrial flutter	2	1
Atrial tachycardia	2	1

JET: Junctional ectopic tachycardia, SVT: Supraventricular tachycardia

Abdelaziz O et al. Ann Pediatr Cardiol 2014 Jan-Apr; 7(1): 19–24.

Most important arrhythmias

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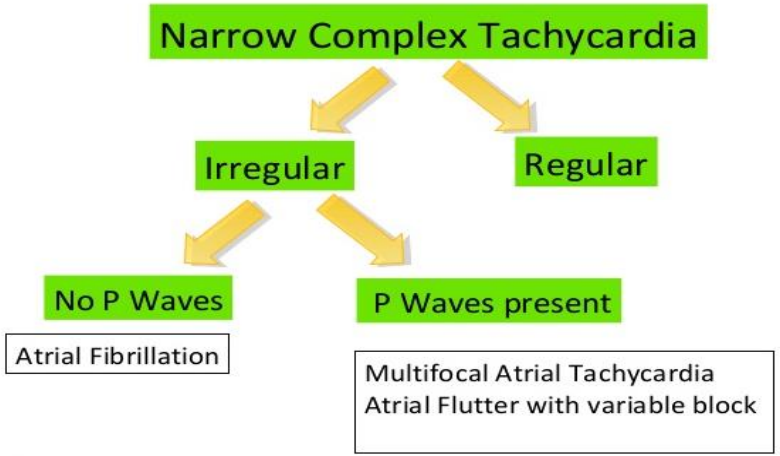
- **Junctional ectopic tachycardia**
- **Transient heart block**

Junctional ectopic tachycardia

- A **narrow complex tachycardia** with atrio-ventricular dissociation



- JET is documented most commonly following Tetralogy of Fallot (TOF) repair, AVSD repair, and Senning operation
- JET can be a result of a combination of factors, including underlying heart disease, type of surgical procedure, haemodynamic instability, and electrolyte imbalance, specially hypomagnesemia
- The pathological mechanism in detail is still unclear; is believed to be a result of direct trauma to the AV node and bundle of His

Junctional ectopic tachycardia

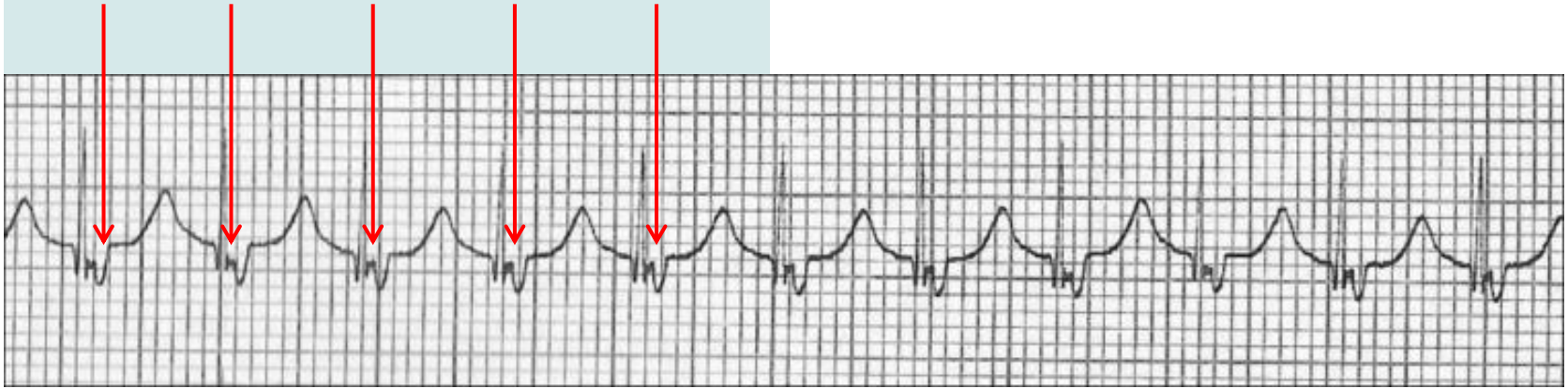
- ECG of patient with JET (using Lewis lead) showing the **P waves dissociated from QRS** with atrial rate less than the ventricular rate

P waves

Junctional ectopic tachycardia

P waves

- ECG of patient with JET (using Lewis lead) showing **retrograde P wave** with 1:1 ventriculoatrial conduction



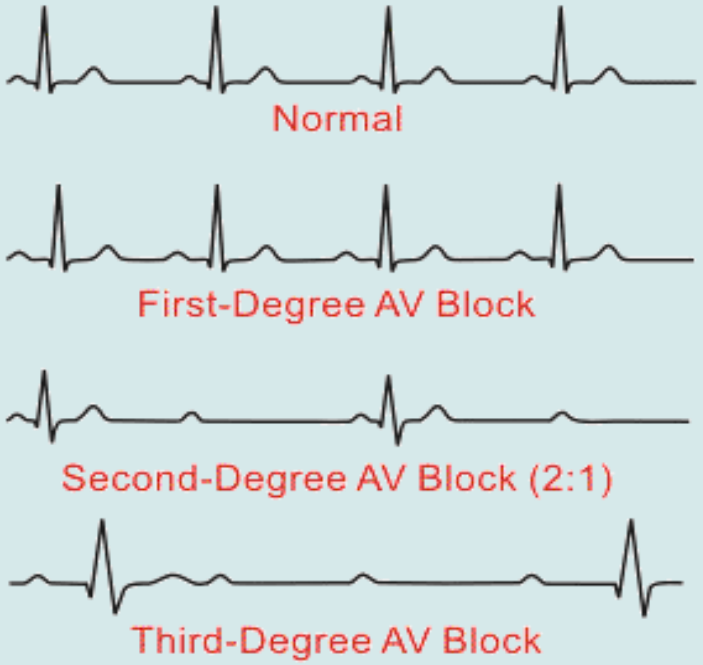
Therapeutic interventions

- **Step 1**:
  - avoid hyperthermia
  - Optimize pain management and anxiolysis
  - optimize electrolytes
  - give magnesium sulfate bolus of 30 mg/kg
- **Step 2**:
  - decrease the catecholamine dose if possible
  - especially stop Dopamine

- **Step 3**:
  - Amiodarone is the first line anti-arrhythmic drug for all patients with haemodynamically compromising JET
  - bolus dose of 5 mg/kg over 2 h followed by continuous infusion of 10-20 mg/kg/24 h.
- **Pacing therapy** can be used for overdrive or sequential pacing **in selected cases**

Transient heart block

- Atrioventricular conduction block (**AV block**) following open-heart surgery for congenital heart disease is uncommon but a well-known complication
- Its incidence ranges between **1 and 3%**
- Early-presenting heart block usually appears during surgery or shortly thereafter



Transient heart block

- The greatest **risk for complete AV block** is associated with corrective surgical procedures for:

  – ventricular septal defects (**VSD**), usually as part of more complex congenital heart disease
  – atrioventricular septal defects (**AVSD**),
  – left ventricular outflow tract obstruction
  – L-transposition of the great arteries
  – Tetralogy of Fallot (**TOF**)
  – discordant atrioventricular connections

Transient heart block

- Most children who require pacing for surgically induced AV block are **less than 1 year old**
- **Spontaneous resolution** of complete AV block in the early postoperative period most often occurring **between 7 and 14 days**

- Complete AV block may resolve spontaneously **in 43 - 92% of children** (Gross et al. 2006)
- Factors associated with a spontaneous recovery of AV nodal function are currently not known

Therapeutic interventions

- Atrial and ventricular **pacing wires are essentials** in every open heart surgery
- Having a sequential pacemaker available, ready, and **knowing how it functioned** are also basic essentials in paediatric cardiac critical care

Temporary pacemakers

- Objectives:
  - explain the situations when temporary pacemakers are indicated
  - describe the **principles of pacing**
  - illustrate normal and abnormal pacemaker behavior
  - discuss the steps to be taken in **troubleshooting** a temporary pacemaker

Indications for temporary pacing

- Bradyarrhythmias
- **AV conduction block**
- Slow sinus or junctional rhythm
- Suppression of ectopy
- Drugs, electrolyte imbalances (Sick Sinus Syndrome)
- Secondary to pronounced atrial stretch
- Old TGA s/p Senning or Mustard procedure

Electrical concept

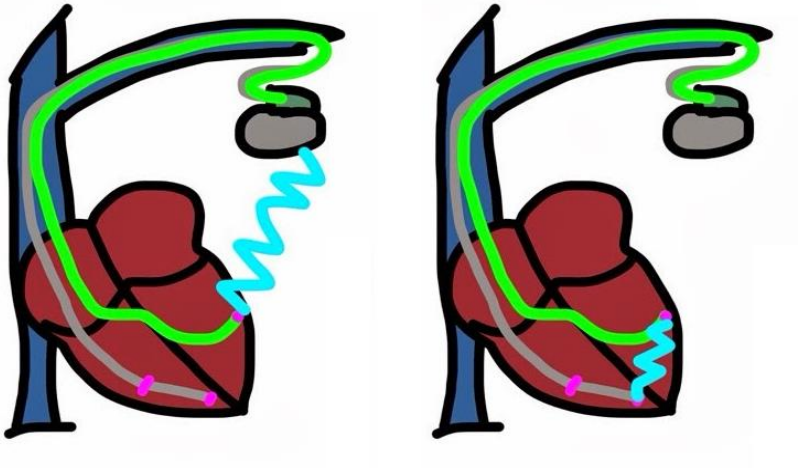
- **Electrical circuit**
  - pacemaker to patient, patient to pacemaker
- **Current**
  - the flow of electrons in a completed circuit; measured in milliamperes (mA)
- **Voltage**
  - a unit of electrical pressure or force causing electrons to move through a circuit; measured in millivolts (mV)
- **Impedance**
  - the resistance to the flow of current

Temporary pacing types

- **Transcutaneous**
  - emergency use with external pacing / defib unit
- **Transvenous**
  - emergency use with external pacemaker
- **Epicardial**
  - wires sutured to right atrium & right ventricle
  - atrial wires exit on the right of the sternum
  - ventricular wires exit on the left of the sternum

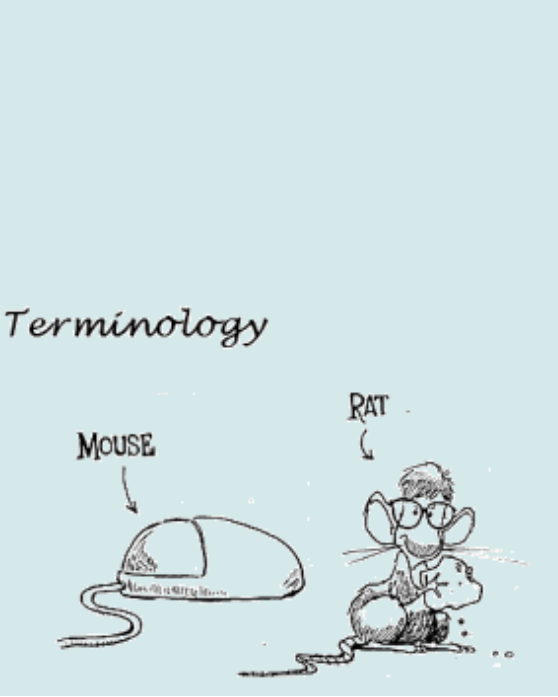
Wiring systems

- **Unipolar**
  - one electrode on the heart (-)
  - signals return through body fluid and tissue to the pacemaker (+)
- **Bipolar**
  - two electrodes on the heart (- / +)
  - signals return to the ring electrode (+) above the lead (-) tip



Overview of terminology

Pace	to deliver an electrical impulse
Sense	ability of the pacemaker to detect intrinsic electrical activity
Pacing Spike	stimulus from the pacemaker recorded on the ECG, a short narrow deflection
Capture	depolarization of the heart by an artificial stimulus; patients myocardial cells capture the impulse delivered by the pacemaker; pacer spike followed by a QRS associated with a pulse

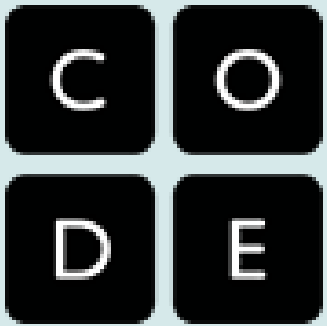


Modes of pacing

- **Atrial pacing**
  - intact AV conduction system required
- **Ventricular pacing**
  - loss of atrial kick
  - discordant ventricular contractions
  - sustains cardiac output
- **Atrial / Ventricular pacing**
  - natural pacing
  - atrial-ventricular synchrony

3-letter NBG temporary code

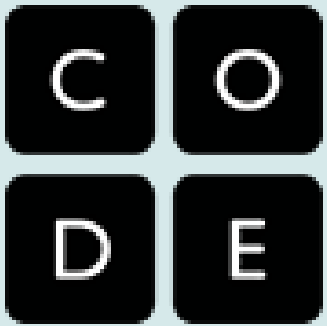
- **First Letter:**



- **Chamber Paced**
  - V - Ventricle
  - A - Atrium
  - D - Dual (A + V)
  - O - None

3-letter NBG temporary code

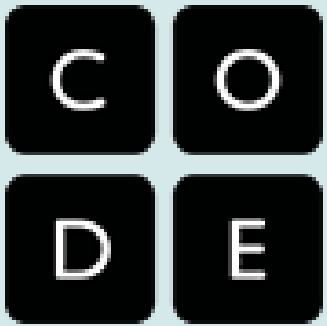
- **Second letter:**



- **Chamber Sensed**
  - V - Ventricle
  - A - Atrium
  - D - Dual (A & V)
  - O - None

3-letter NBG temporary code

- **Third letter:**



- **Sensed Response**
  - T - Triggers Pacing
  - I - Inhibits Pacing
  - D - Dual
  - O - None

Commonly used modes

- **AAI**
  - atrial demand pacing
- **VVI**
  - ventricular demand pacing
- **DDD**
  - atrial/ventricular demand pacing, senses and paces both chambers; trigger or inhibit
- **AOO**
  - atrial asynchronous pacing

Settings

- **Atrial and ventricular output**
  - milliamperes (mA)
  - typical atrial: mA 5
  - typical ventricular: mA 8 - 10
- **AV Interval**
  - milliseconds (msec)
  - time from atrial sense/pace to ventricular pace
  - synonymous with “PR” interval

- **Atrial and ventricular sensitivity**
  - millivolts (mV)
  - typical atrial: 0.4 mV
  - typical ventricular: 2.0mV

Settings

- **Atrial/ventricular rate**
  - set at physiologic rate for individual patient
  - AV Interval, upper rate, + PVARP automatically adjust with set rate changes
- **Upper rate**
  - automatically adjusts to 30 bpm higher than set rate
  - prevents pacemaker mediated tachycardia from unusually high atrial rates
  - Wenckebach-type rhythm results when atrial rates are sensed faster than the set rate

- **Refractory period**
  - PVARP: Post Ventricular Atrial Refractory Period
  - time after ventricular sensing/pacing when atrial events are ignored

Very important

- **Electrical Safety**
  - microshock
  - accidental de-wiring
  - taping wires
  - securing pacemaker
- **Removal of pacing wires**
  - potential myocardial trauma
  - bleeding
  - pericardial effusion / tamponade
  - haemothorax
  - ventricular arrhythmias

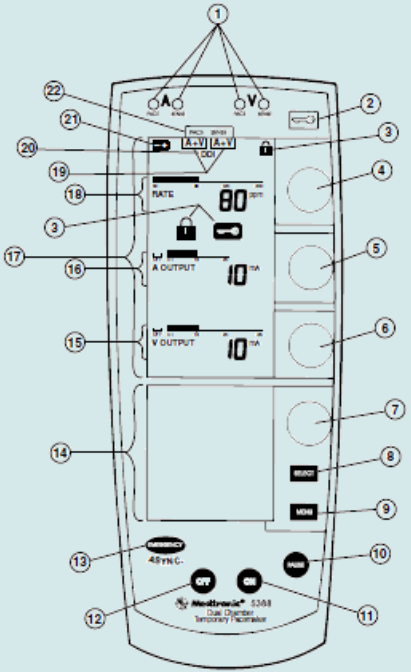
- **Pacemaker care & cleaning**
  - batteries
  - bridging cables
  - pacemakers

Pacemaker

- **Medtronic 5388 Dual Chamber (DDD)**

Pacemaker

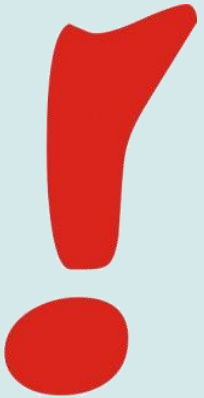
- **Medtronic 5388 Dual Chamber (DDD)**



Pacemaker ECG

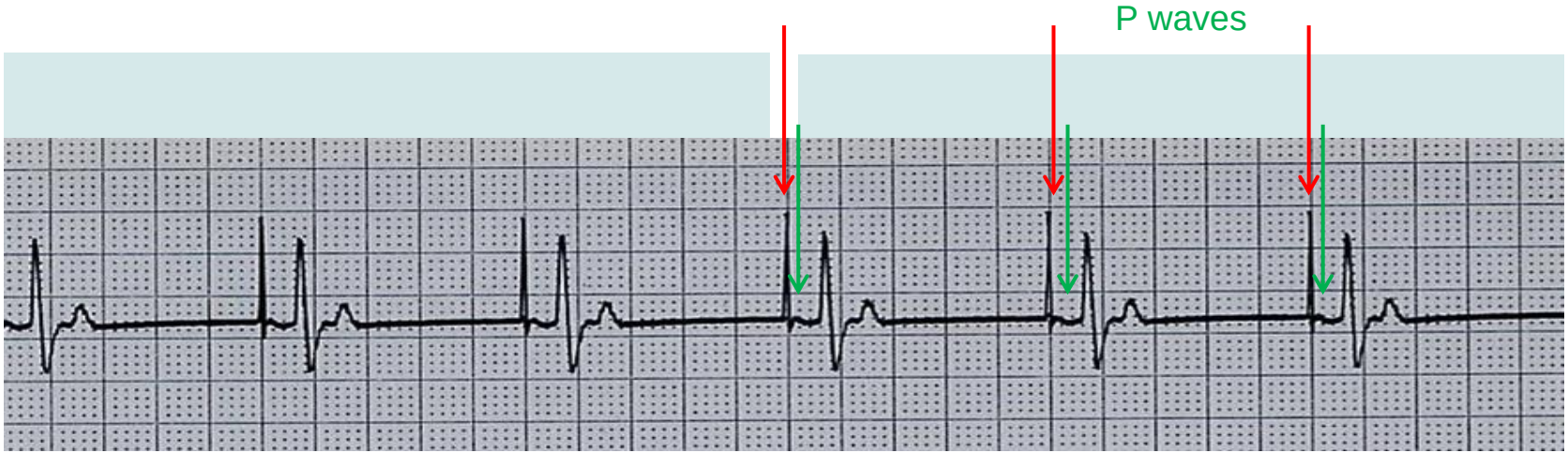
- Assessing paced ECG
- Identify intrinsic rhythm and clinical condition
- Identify pacer spikes
- Identify activity following pacer spikes
- Failure to capture
- Failure to sense

- Every pacer spike should have a P - wave or QRS complex following it!



Normal pacing

- **Atrial pacing:**
  - atrial pacing spikes followed by P waves

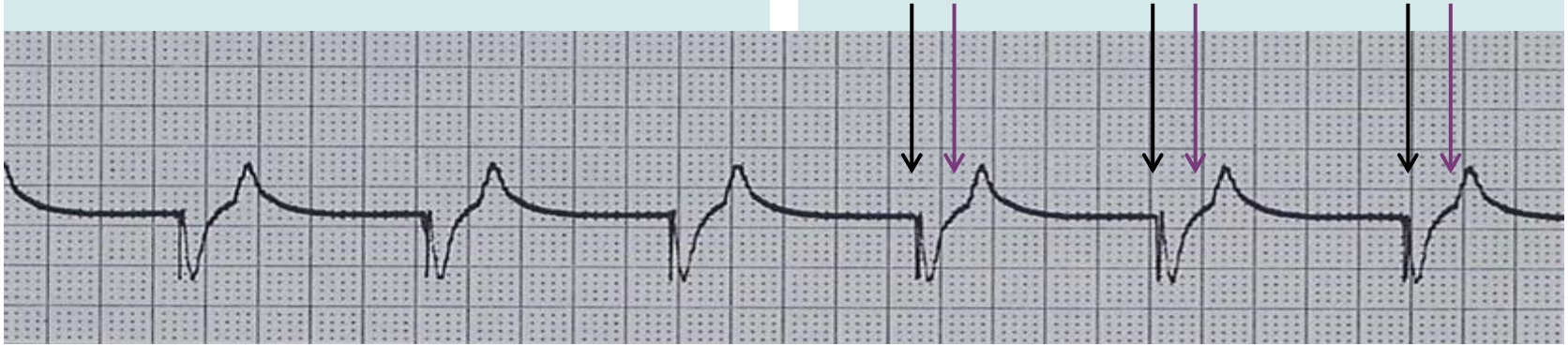


Normal pacing

- **Ventricular pacing:**
  - ventricular pacing spikes followed by wide, bizarre QRS complexes

Ventricular pacing spikes

QRS complexes

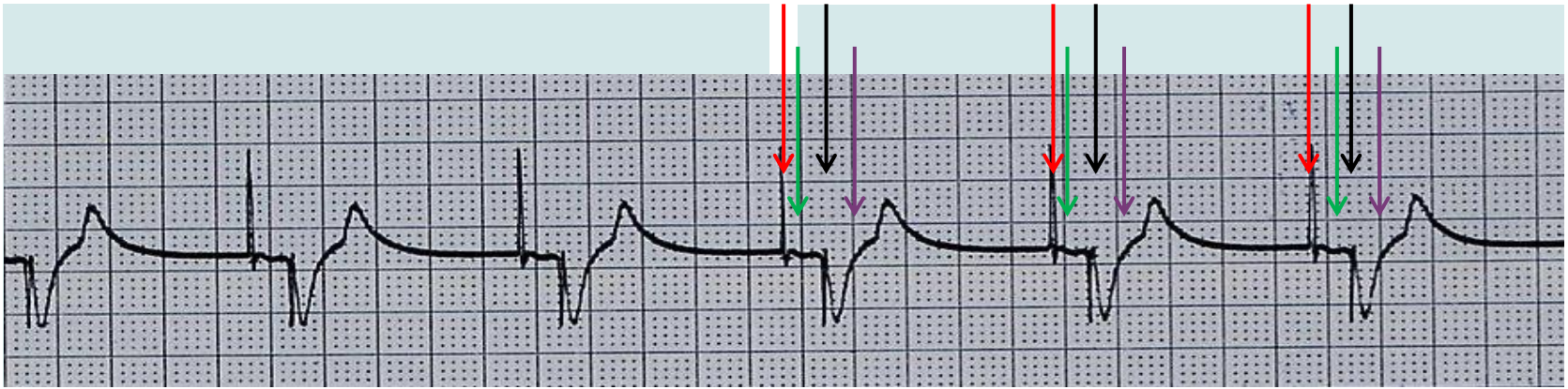


Normal pacing

- **A-V Pacing:**
- atrial + ventricular pacing spikes followed by atrial + ventricular complexes

Atrial + Ventricular pacing spikes

Atrial + QRS complexes

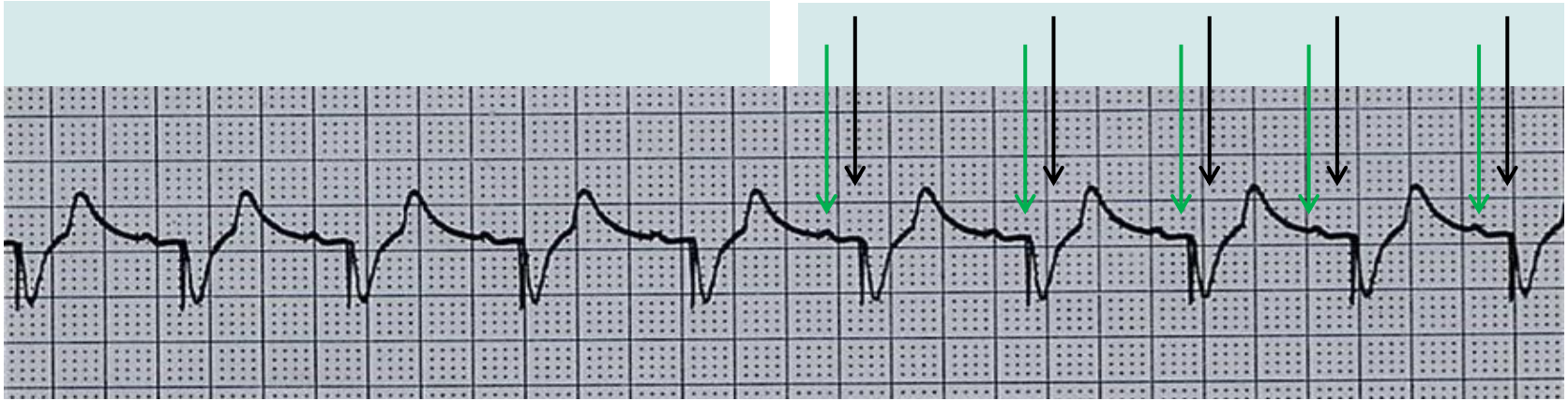


Normal pacing

- **DDD mode of pacing:**
  - ventricle paced at atrial rate

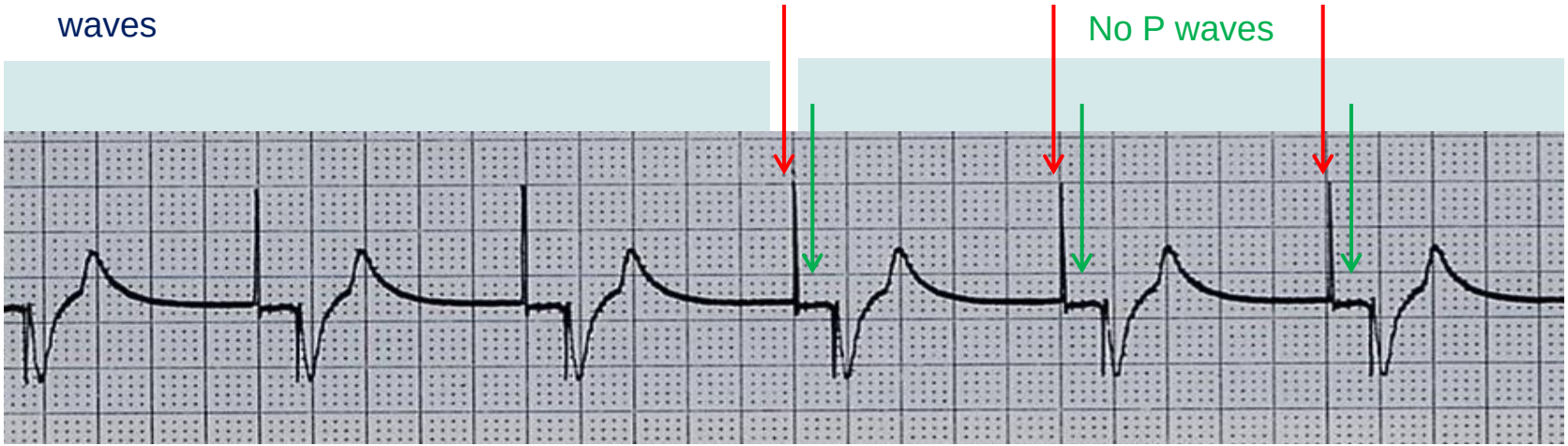
Ventricular pacing spikes

P waves



Abnormal pacing

- **Atrial non-capture:**
  - atrial pacing spikes are not followed by P waves

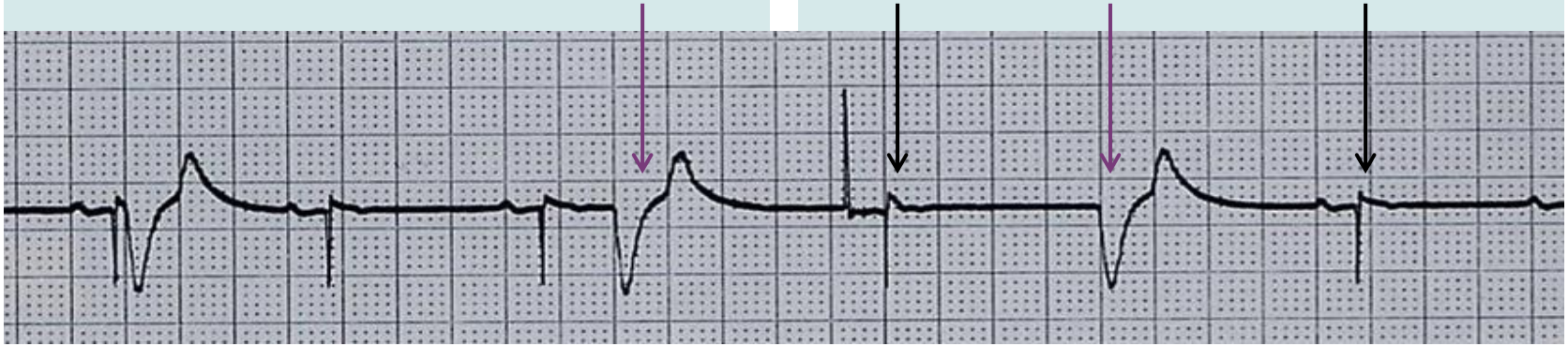


Abnormal pacing

- **Ventricular non-capture:**
  - ventricular pacing spikes are not followed by QRS complexes

Ventricular pacing spikes

QRS complexes



Failure to capture

- **Causes:**
  - insufficient energy delivered by pacer
  - low pacemaker battery
  - dislodged, loose, fibrotic, or fractured electrode
  - electrolyte abnormalities
    - acidosis
    - hypoxemia
    - hypokalemia

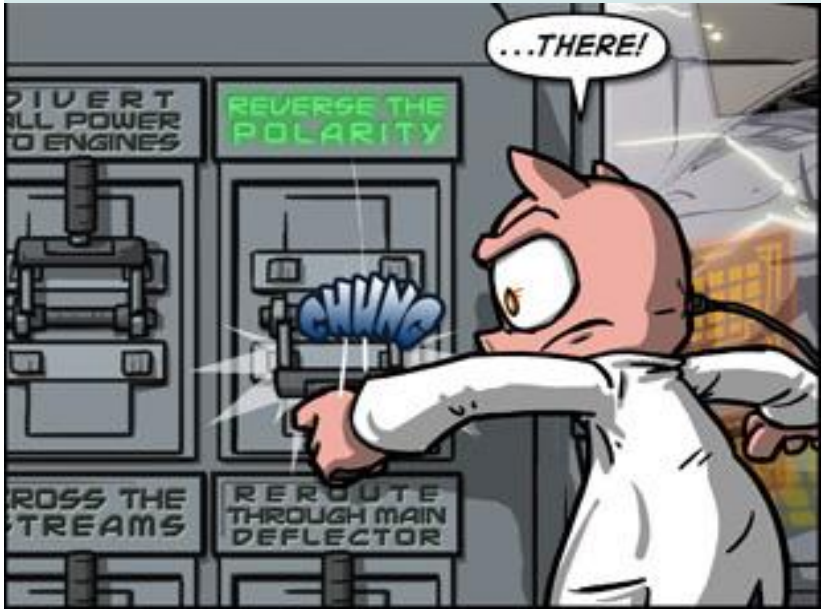
- **Danger:**
  - poor cardiac output

Failure to capture

- **Solutions:**
  - view rhythm in different leads
  - change electrodes
  - check connections
  - **increase pacer output (↑mA)**
  - change battery, cables, pacer
  - reverse polarity

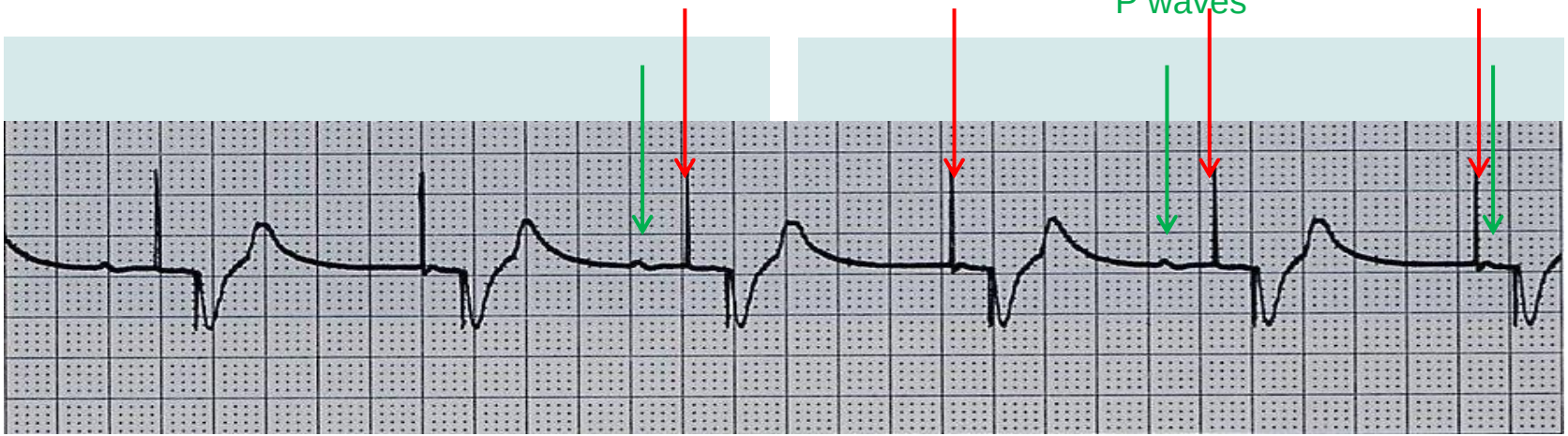
Reversing polarity

- **Changing polarity:**
  - Requires bipolar wiring system
  - Reverses current flow
  - Switch wires at pacing wire/bridging cable interface
  - Skin “ground” wire



Abnormal pacing

- **Atrial undersensing:**
  - atrial pacing spikes occur irregardless of P waves
  - pacemaker is not “seeing” intrinsic activity

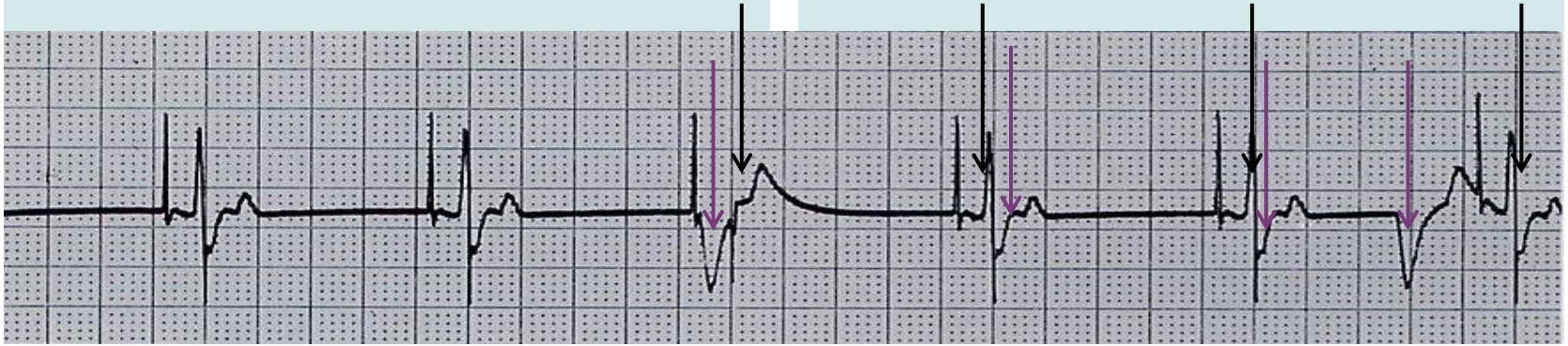


Abnormal pacing

- **Ventricular undersensing:**
  - ventricular pacing spikes occur regardless of QRS complexes
  - pacemaker is not “seeing” intrinsic activity

Ventricular pacing spikes

QRS complexes



Failure to sense

- **Causes:**
  - pacemaker not sensitive enough to patient's intrinsic electrical activity (mV)
  - insufficient myocardial voltage
  - dislodged, loose, fibrotic, or fractured electrode
  - electrolyte abnormalities
  - low battery
  - malfunction of pacemaker or bridging cable

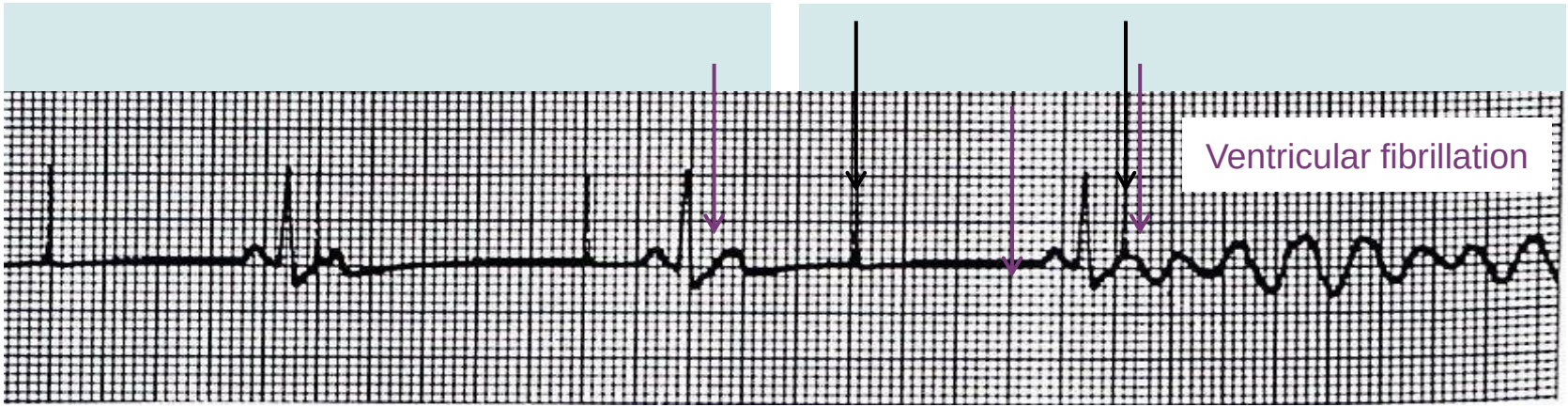
Failure to sense

- **Danger:**
  - potential (low) for paced ventricular beat to land on T wave

  R- on -T phenomenon

Ventricular pacing spikes

QRS complexes

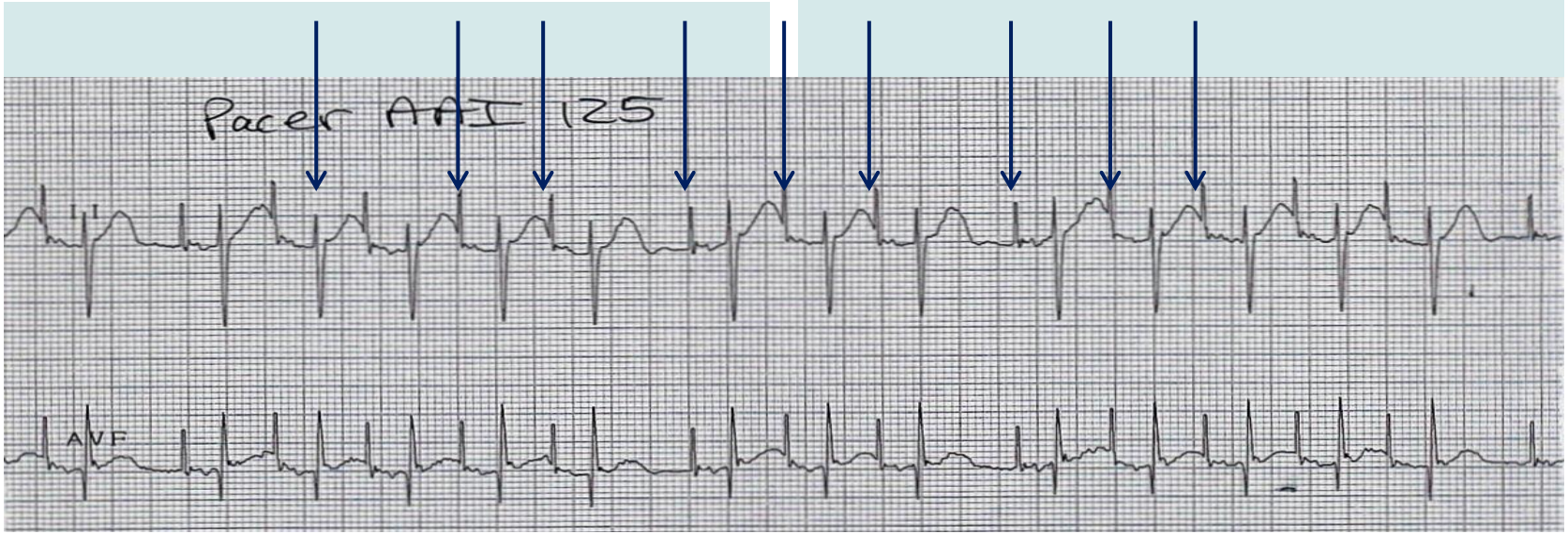


Failure to sense

- **Solution:**
  - view rhythm in different leads
  - change electrodes
  - check connections
  - **increase pacemaker's sensitivity (↓mV)**
  - change cables, battery, pacemaker
  - reverse polarity
  - check electrolytes
  - unipolar pacing with subcutaneous "ground wire"

Oversensing

- Pacing does not occur when intrinsic rhythm is inadequate



Oversensing

- **Causes:**
  - pacemaker inhibited due to sensing of P - waves + QRS complexes that do not exist
  - pacemaker too sensitive
  - possible wire fracture, loose contact
  - pacemaker failure

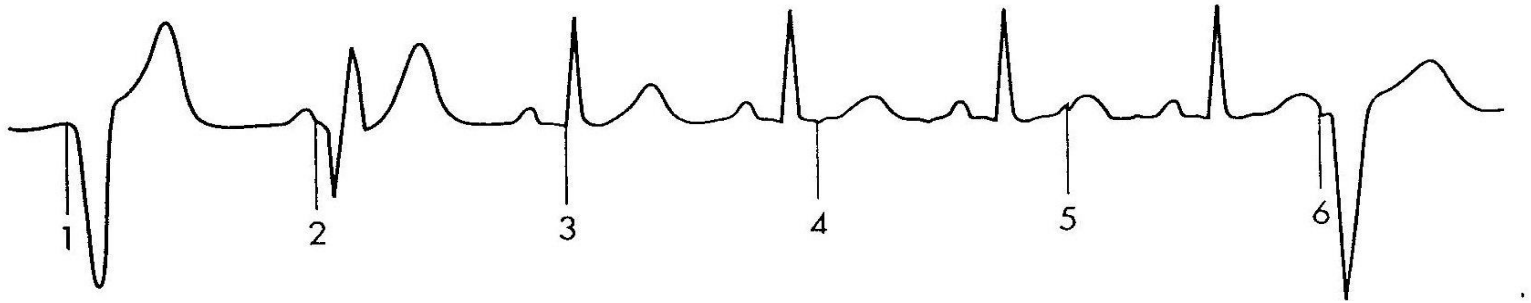
- **Danger:**
  - heart block, asystole

Oversensing

- **Solution:**
  - view rhythm in different leads
  - change electrodes
  - check connections
  - **decrease pacemaker sensitivity (↑mV)**
  - change cables, battery, pacemaker
  - reverse polarity
  - check electrolytes
  - unipolar pacing with subcutaneous “ground wire”

Competition

- **Assessment:**
  - pacemaker + patient's intrinsic rate are similar
  - unrelated pacer spikes to P wave, QRS complex
  - fusion beats



Competition

- **Causes:**
  - asynchronous pacing
  - failure to sense
  - mechanical failure: wires, bridging cables, pacemaker
  - loose connections

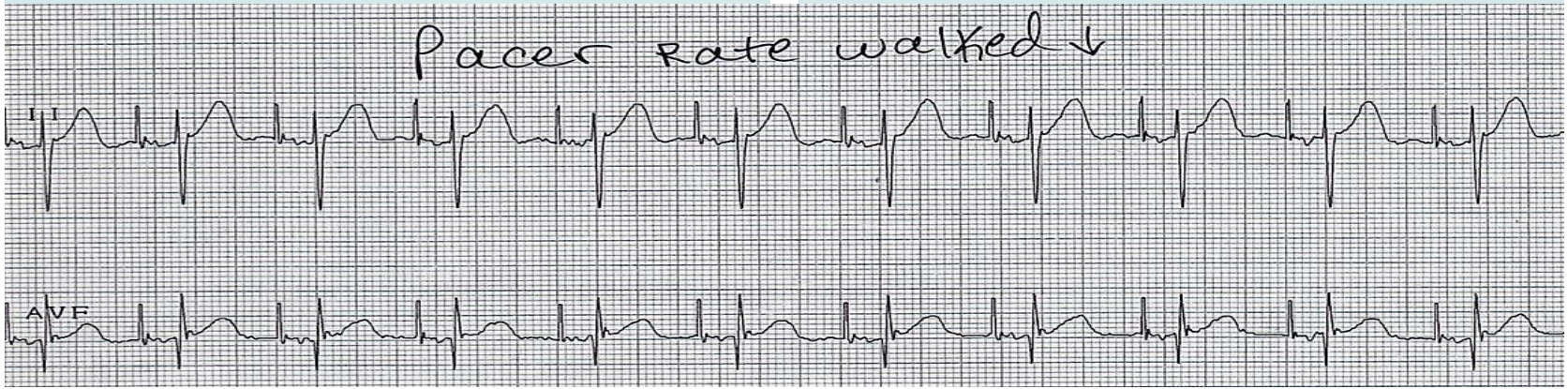
- **Danger:**
  - impaired cardiac output
  - potential (low) for paced ventricular beat to land on T wave

Competition

- **Solution:**
  - Assess underlying rhythm
  - slowly turn pacer rate down
  - troubleshoot as for failure to sense
  - **increase pacemaker sensitivity (↓mV)**
  - increase pacemaker rate

Assessing Underlying Rhythm

- Carefully assess underlying rhythm:
  - right way: slowly decrease pacemaker rate

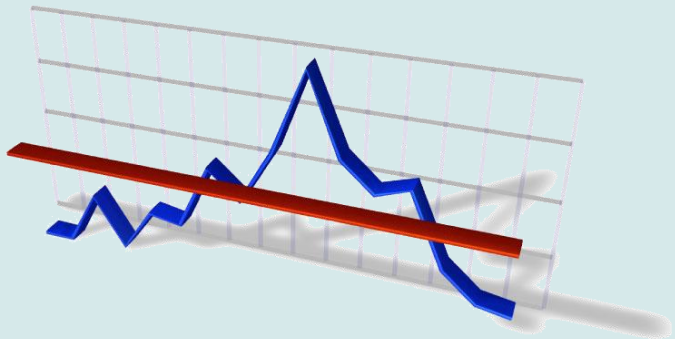


Stimulation threshold

- **Definition:**
  - minimum current necessary to capture + stimulate the heart

Stimulation threshold

- **Testing:**
  - set pacer rate 10 ppm faster than patient's HR
  - decrease mA until capture is lost
  - increase output until capture is regained (threshold capture)
  - output setting to be 2x's threshold capture



Sensitivity threshold

- **Definition:**
  - minimum level of intrinsic electric activity generated by the heart detectable by the pacemaker

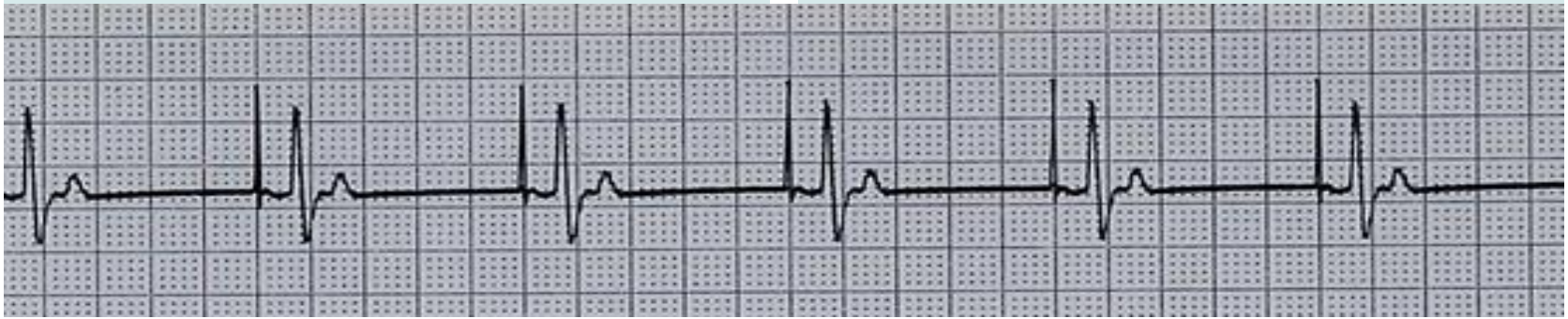
Sensitivity threshold

- **Testing:**

– set pacer rate 10 ppm slower than patient's HR
– increase sensitivity to chamber being tested to minimum level (0.4mV)
– decrease sensitivity of the pacer (↑mV) to the chamber being tested until pacer stops sensing patient (orange light stops flashing)
– increase sensitivity of the pacer (↓mV) until the pacer senses the patient (orange light begins flashing).
– this is the threshold for sensitivity
– set the sensitivity at ½ the threshold value
– example: Set sensitivity at 1mV if the threshold was 2mV

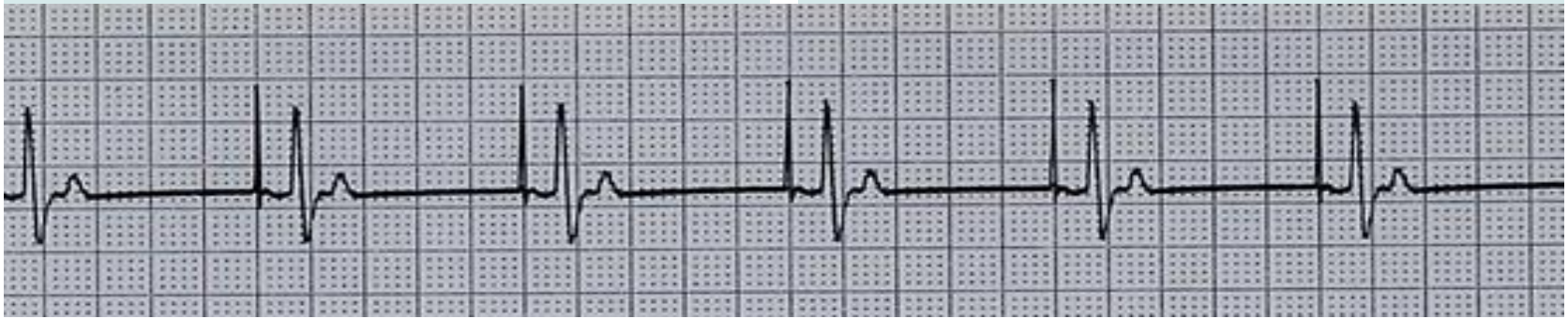
Mode of pacing:
rhythm / problem / solution

What does it show?



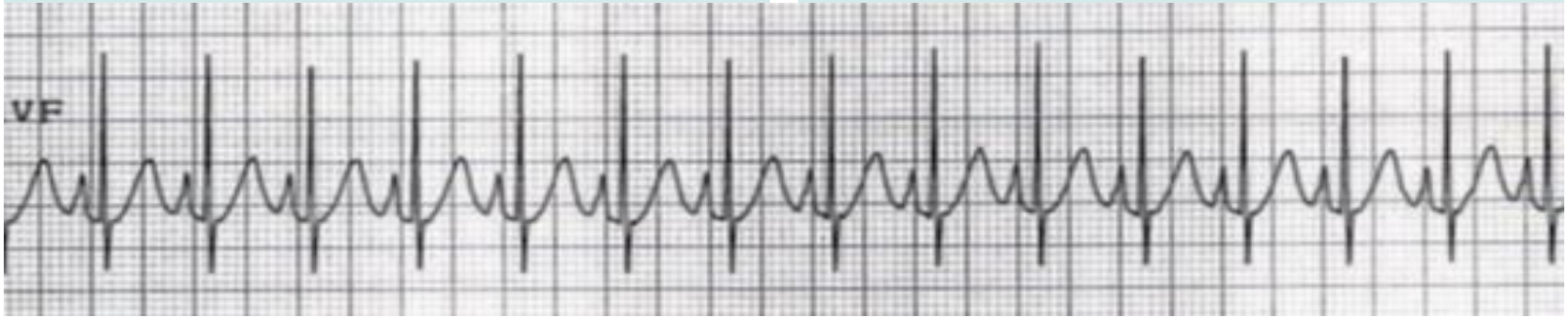
Mode of pacing: rhythm / problem / solution

- **VVI**
  - ventricular pacing



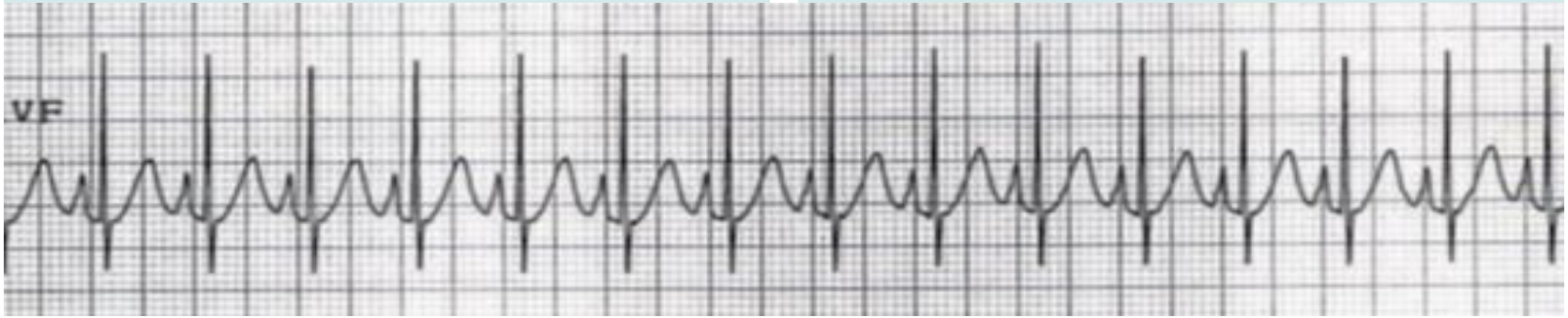
Mode of pacing:
rhythm / problem / solution

What does it show?



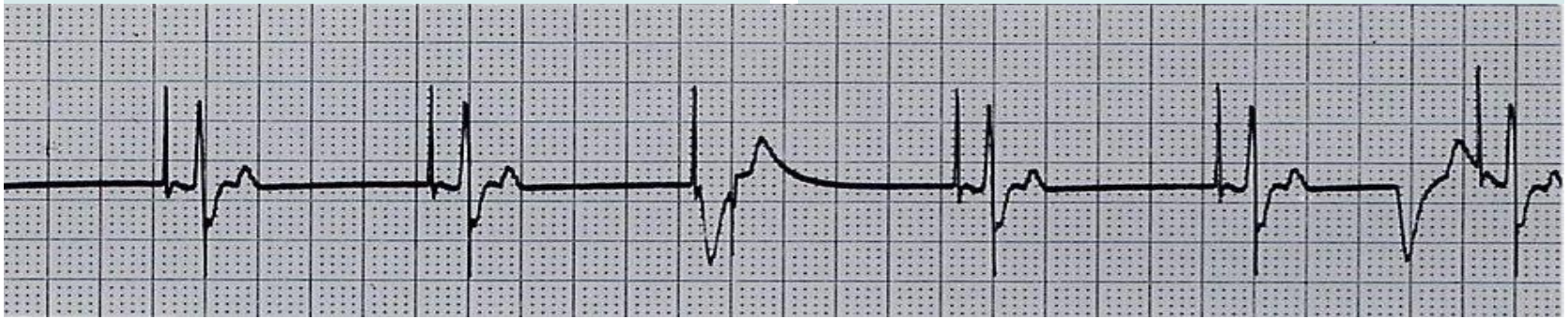
Mode of pacing: rhythm / problem / solution

- **Sinus rhythm**
  - no pacing
  - possible back-up setting AAI, VVI, DDD



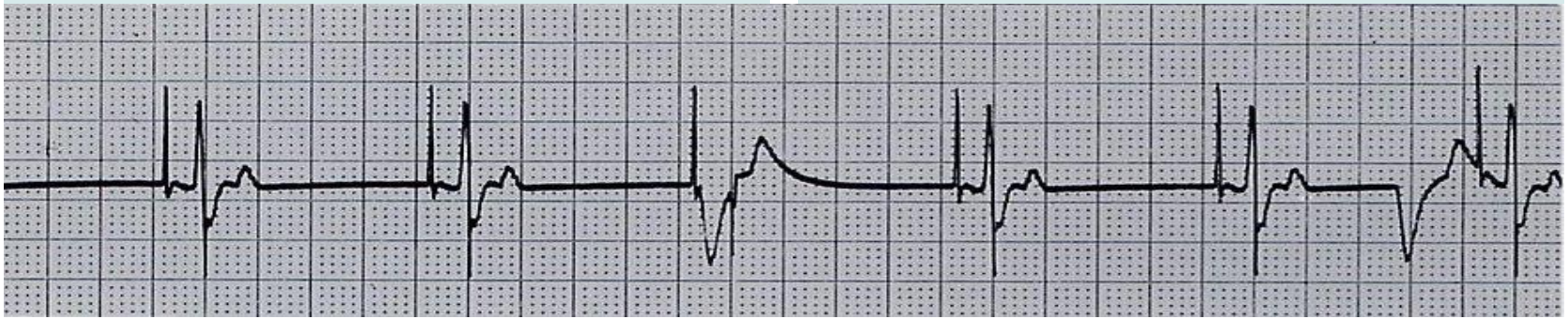
Mode of pacing, rhythm/problem, solution

What does it show?



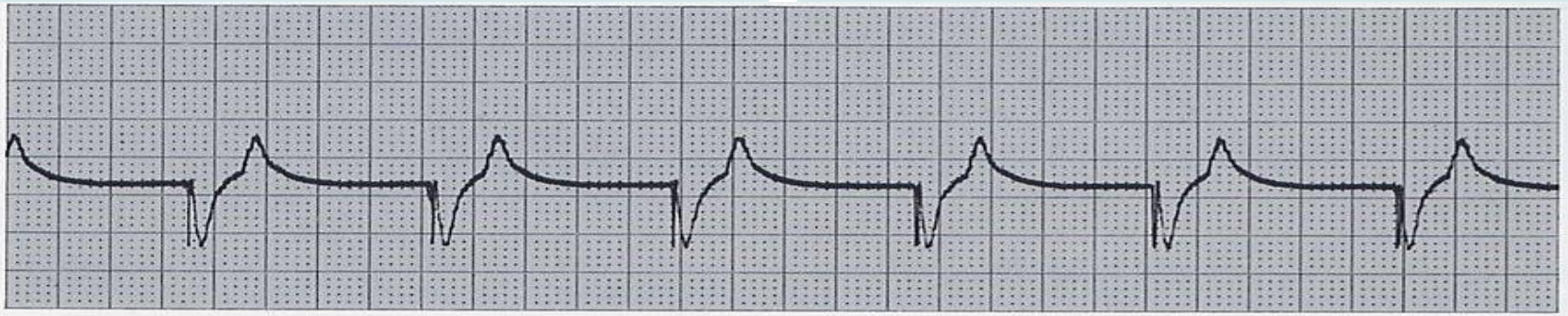
Mode of pacing, rhythm/problem, solution

- **DDD**
  - failure to sense ventricle
  - increase ventricular mA



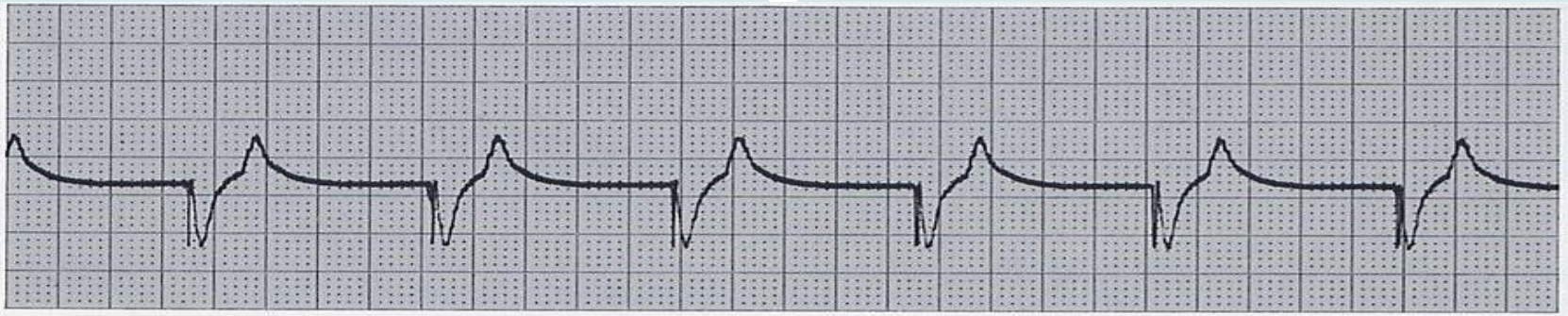
Mode of pacing, rhythm/problem, solution

What does it show?



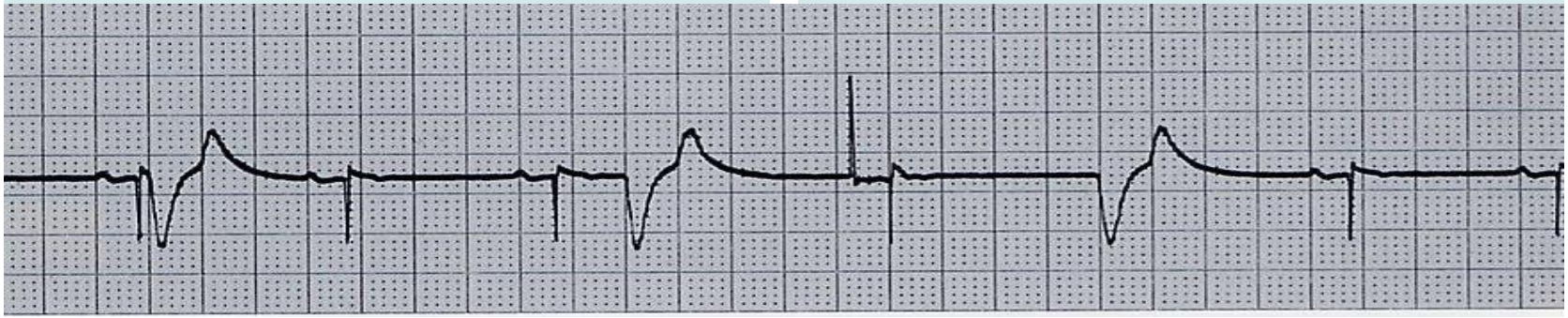
Mode of pacing, rhythm/problem, solution

- **VVI**
  - ventricular pacing



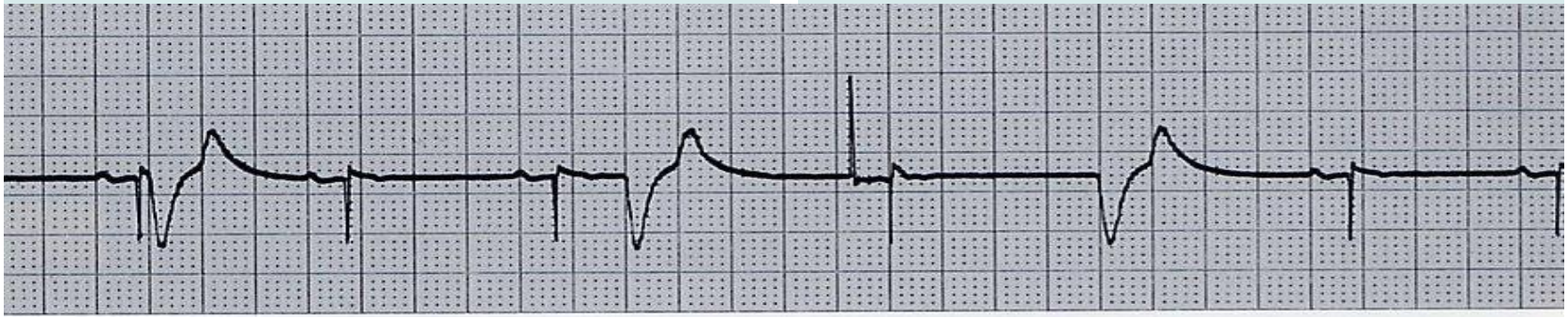
Mode of pacing, rhythm/problem, solution

What does it show?



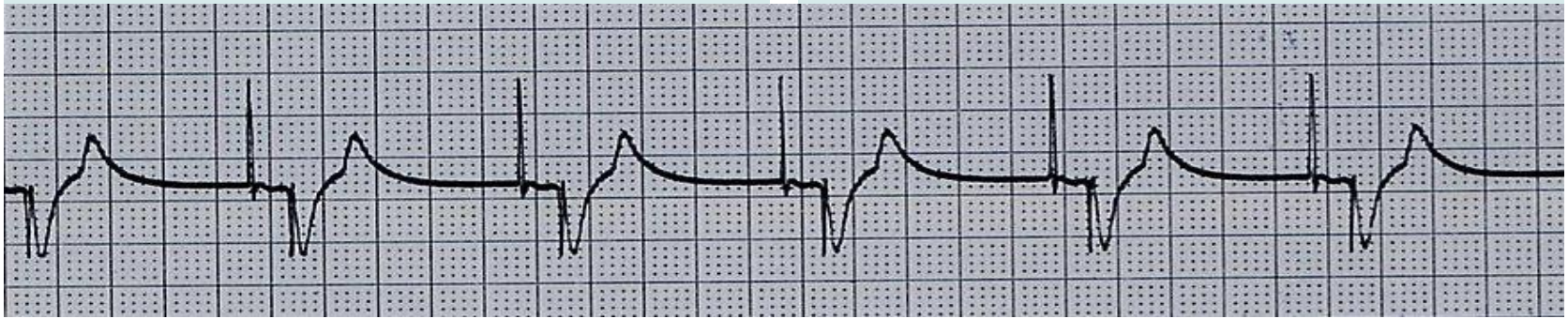
Mode of pacing, rhythm/problem, solution

- **DDD**
  - failure to capture atrial or ventricle
  - increase atrial & ventricular mA



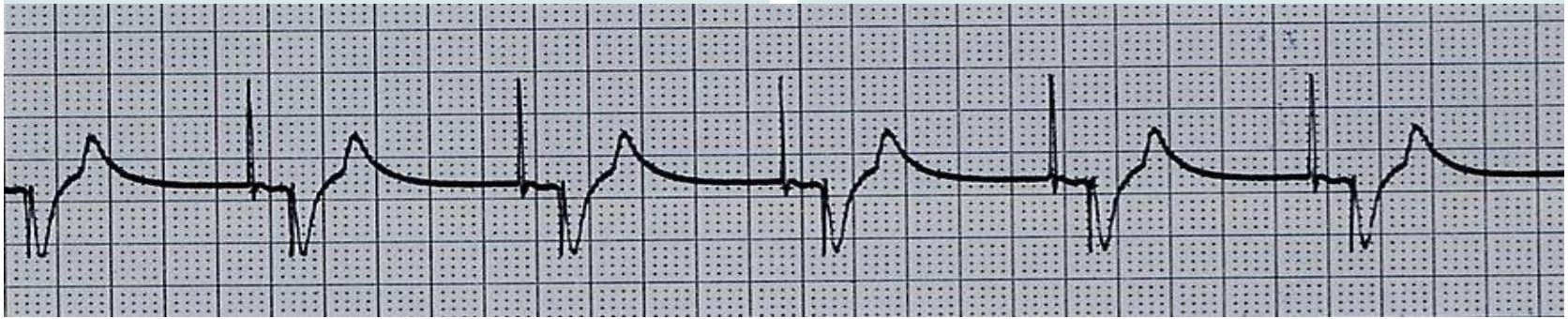
Mode of pacing, rhythm/problem, solution

What does it show?



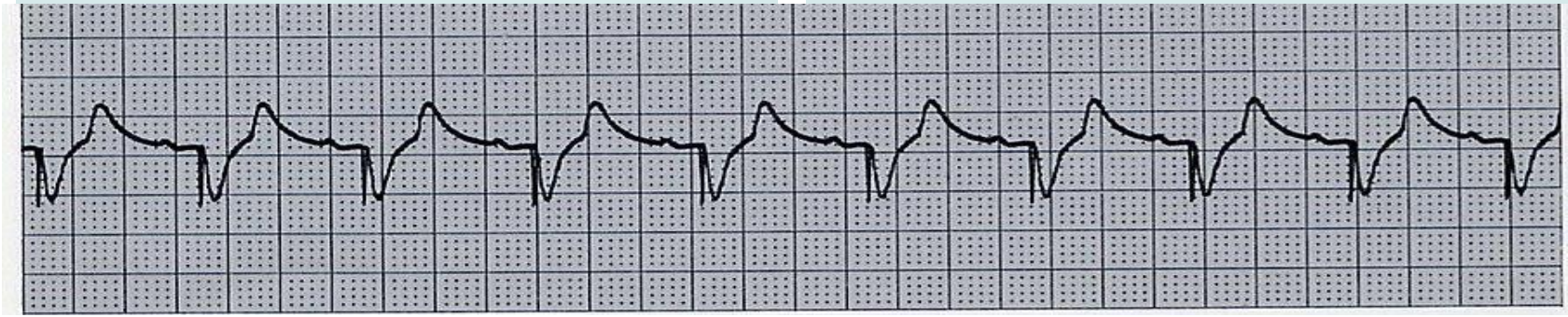
Mode of pacing, rhythm/problem, solution

- **DDD**
  - normal atrial + ventricular pacing



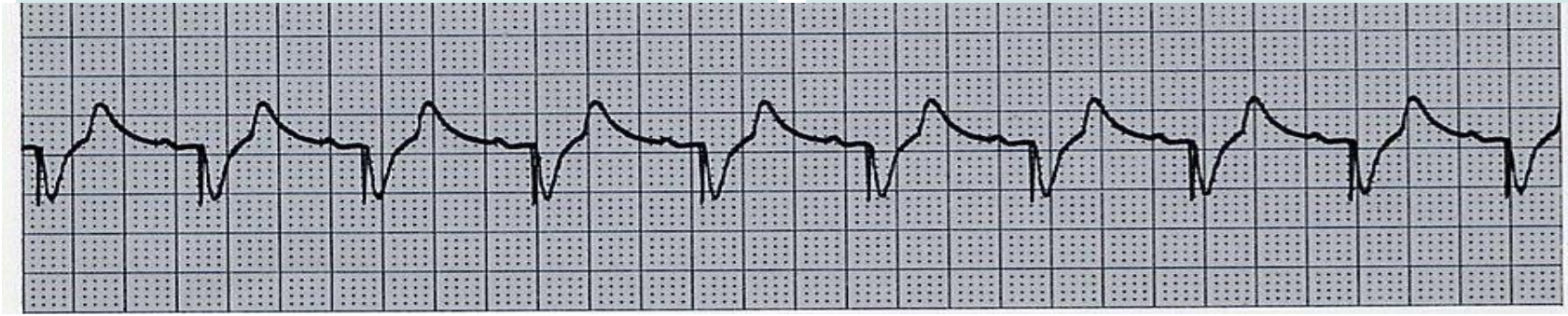
Mode of pacing, rhythm/problem, solution

What does it show?



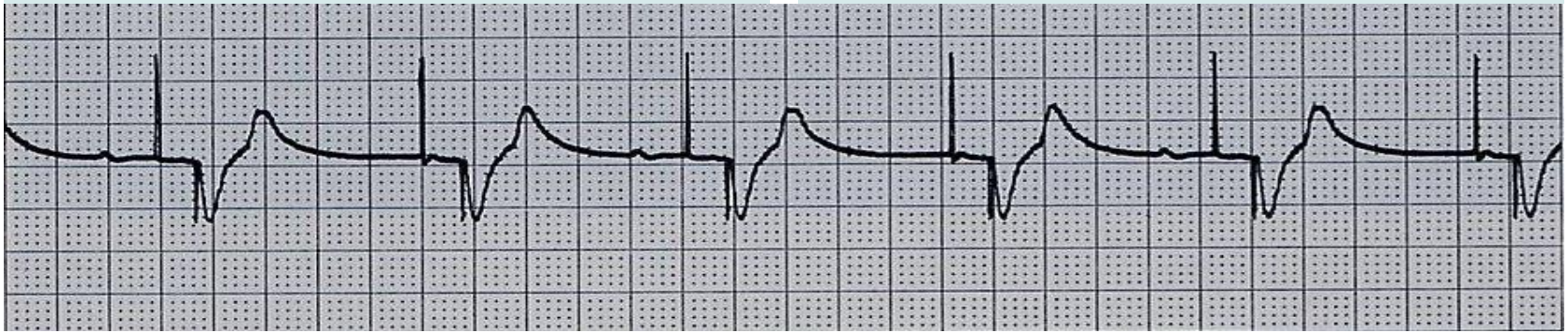
Mode of pacing, rhythm/problem, solution

- **DDD**
  - normal atrial sensing
  - ventricular pacing



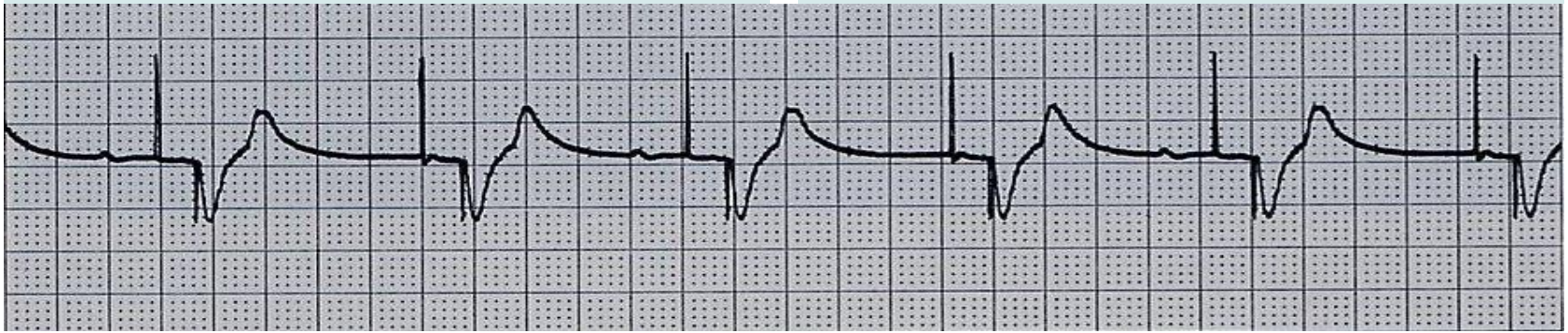
Mode of pacing, rhythm/problem, solution

What does it show?



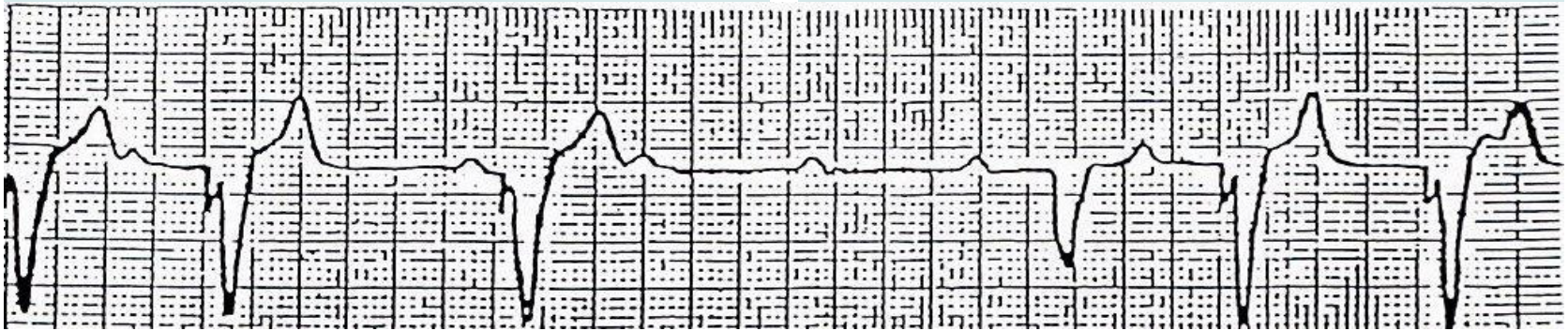
Mode of pacing, rhythm/problem, solution

- **DDD**
  - failure to capture atria
  - increase atrial mA



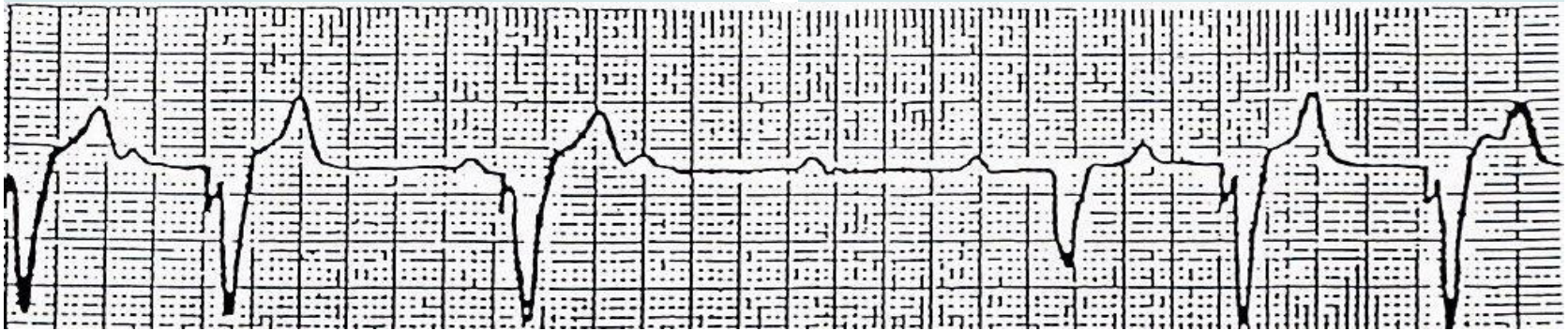
Mode of pacing, rhythm/problem, solution

What does it show?



Mode of pacing, rhythm/problem, solution

- **DDD**
  - Oversensing
  - decrease ventricular sensitivity



Thank you for your attention