

Permanent Cardiac Pacemaker

Andrew Ying-Siu Lee, MD, PhD.

Indications for permanent pacemaker implantation:

Class I indications (definitely needed, appropriate):

- **Complete heart block, permanent or intermittent, associated with cardiac or cerebral symptoms, as:**
 - **symptomatic bradycardia**
 - **heart failure**
 - **asystole > 3 sec or escape rate < 40 beats/min**
 - **confusion**
 - **postoperative complete heart block not expected to resolve**
 - **AV node ablation**

- **second degree heart block, permanent or intermittent, with symptomatic bradycardia**
- **atrial fibrillation or flutter with high grade heart block and bradycardia unrelated to drugs**
- **persistent high grade heart block after acute myocardial infarction**
- **bi- or trifascicular block and intermittent complete or Mobitz II heart block**

Class II indications (possibly needed, equivocal):

- **asymptomatic complete or high grade heart block**
- **symptomatic heart rate < 40 beats/min**

Class III indications (not needed, inappropriate):

- **transient heart block expected to resolve**
- **asymptomatic heart rate < 40 beats/min**

Pacing mode

■ Pacing Code:-

1st letter = chamber paced eg. V=ventricle, A=atrium, D=dual,
O= none

2nd = chamber sensed eg. V=ventricle, A=atrium, D=dual,
O= none

3rd = response to sensing eg. T=triggers pacing, I=inhibits
pacing, D=triggers and inhibits pacing, O=none

4th = programmability eg. P=programmable, M=multi-
programmable, C=telemetry, R=rate-responsive, O=none

5th = antiarrhythmic functions eg. P=antitachycardia pacing,
S=shock, D=dual (Pace and shock), O=none

Thus, DDDR pacing mode = (1)paces dual chambers (atrium and ventricle), (2) senses dual chambers, (3) responds to sensed events in dual manner (inhibits or triggers), (4) provides rate modulation (to match patient's activity level)

Selection of pacing mode

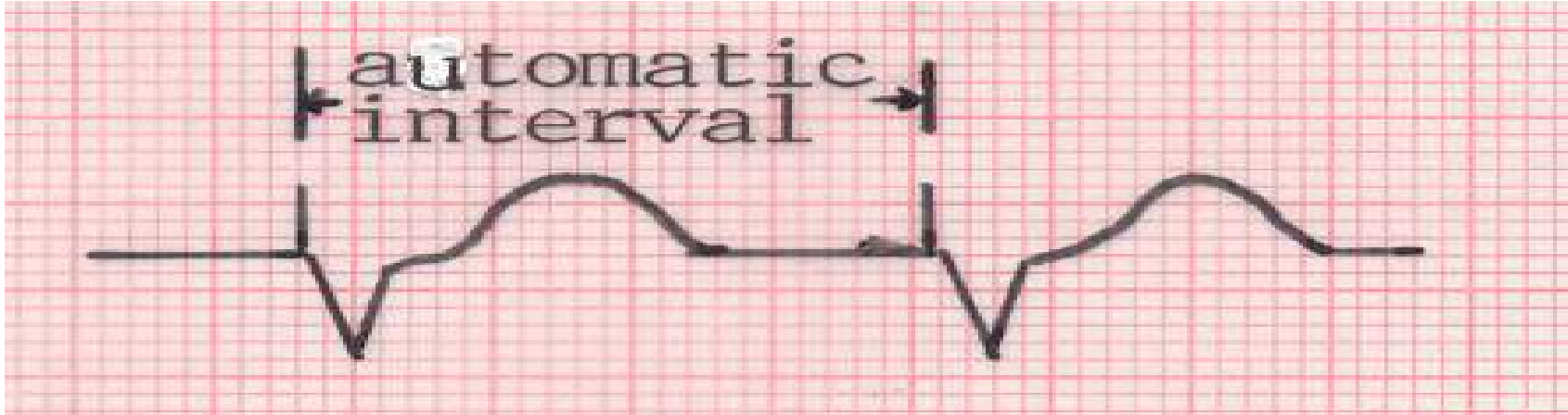
- Single chamber mode): for chronic atrial fibrillation (fibrillating atria cannot be paced)
- Dual chamber modes : for heart block or intermittent atrial arrhythmias
- Preferred pacing modes:
 - Sick sinus syndrome – DDDR
 - AAIR (if no atrial arrhythmia and normal AV node function)
 - VVIR (if atrial fibrillation)
 - Heart block – DDD (if suspect sinus node disease = mode of choice)
 - VDD (if no sinus node disease)
 - VVIR (if atrial fibrillation)

Electrical Concepts

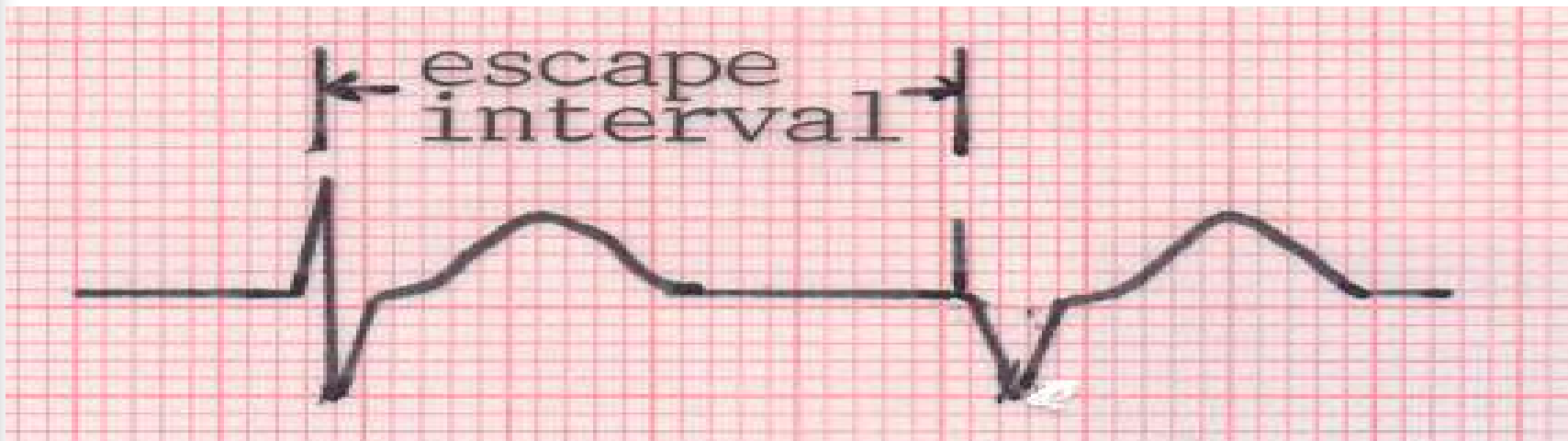
- Measurement by “pacing system analyzer”
- V = voltage (force moving current)
- I = current (volume of electric flow), amperes
- Impedance = resistance to electric flow, ohms, normal = 250 – 2000
- Ohm's law of electricity : current = voltage/resistance
- Capture threshold = minimal generator output required to stimulate heart contraction
 - atrium < 1.5 volts
 - ventricle < 1 volt
 - current threshold: 1.5-2 mA
- Sensing threshold = pacemaker's capacity to sense patient's intrinsic heartbeat, detected as local electrogram in millivolts
 - atrium > 1.5 mV ventricle > 5 mV
- Slew rate = rate of change of voltage or slope (volts/second). Sufficient rapid slew rate ensures good long-term sensing

Single chamber pacing

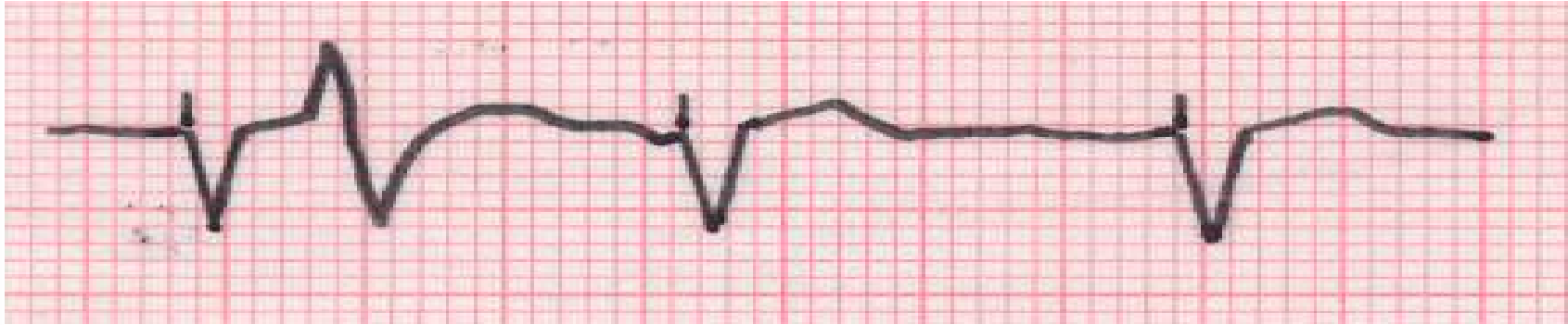
- **Automatic interval** = base pacing interval
= time period between 2 sequential paced beats



- **Escape interval** = time period from when an intrinsic beat is sensed until a paced beat will

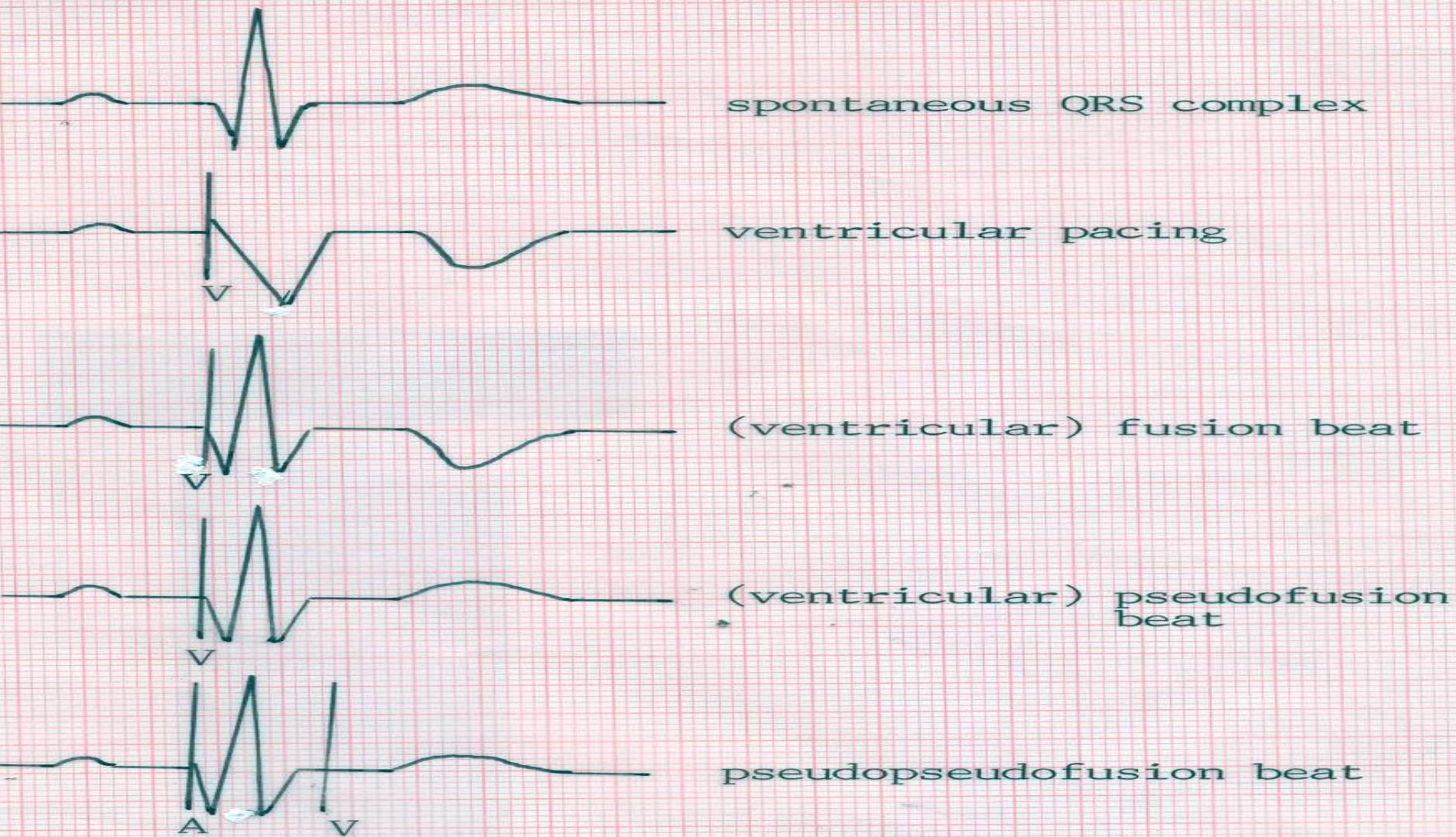


- **Refractory period** =time period after a paced or sensed event during which the pacemaker sensing is disabled



- **Hysteresis** =special lower rate (=hysteresis rate) than the automatic interval refraining the pacemaker from pacing frequently. Useful for patients with infrequent pacing needs or symptomatic during pacing





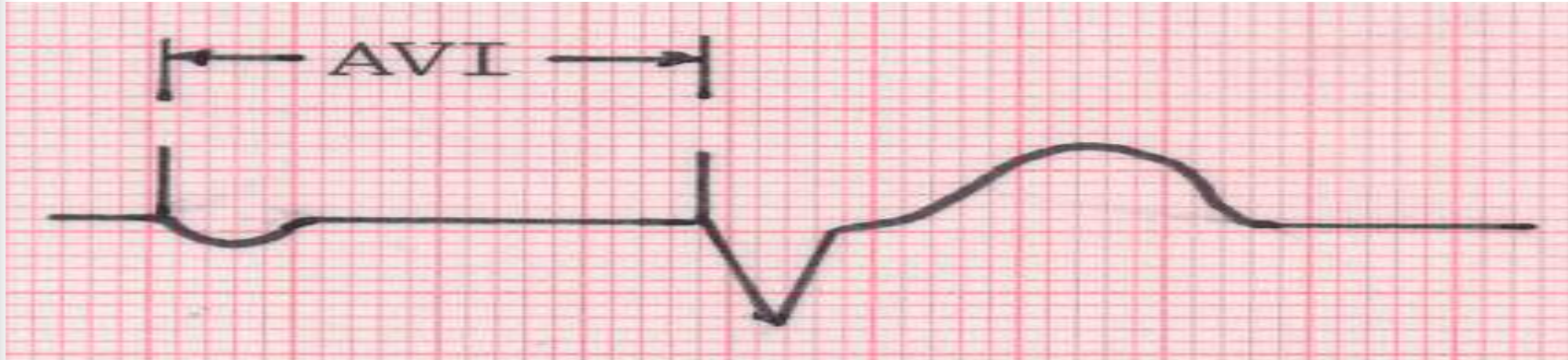
Fusion = ventricle depolarized by both pacing and spontaneous stimuli → QRS and T wave configuration intermediate between spontaneous and paced complex

Pseudofusion = pacing stimulus no effect on ventricular depolarization which is entirely spontaneous and neither QRS or T wave are modified.

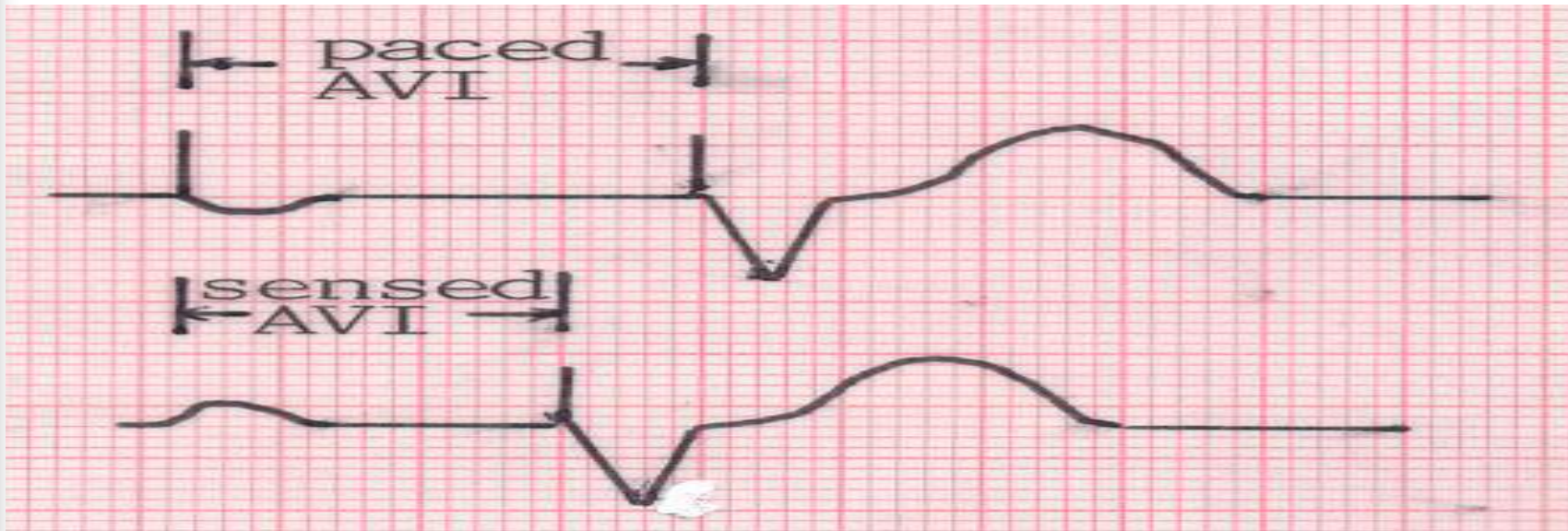
Pseudo-pseudofusion :atrial stimulus coincides incidentally with spontaneous QRS complex

Dual chamber pacing

- **AV interval (AVI, AV delay)** = time period elapse after a paced or sensed atrial event before a ventricular impulse will be delivered.
Normal = 12 – 50 msec



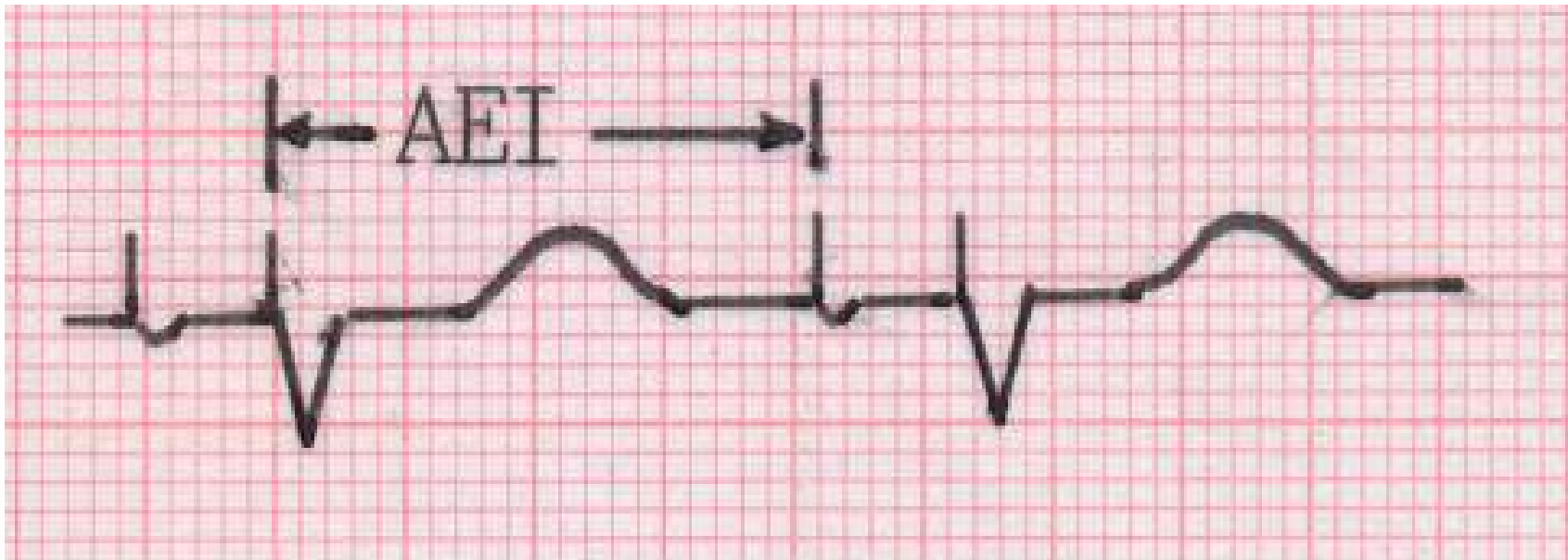
- **Differential AV interval** = AVI following a sensed P wave is shorter than that following a paced P wave



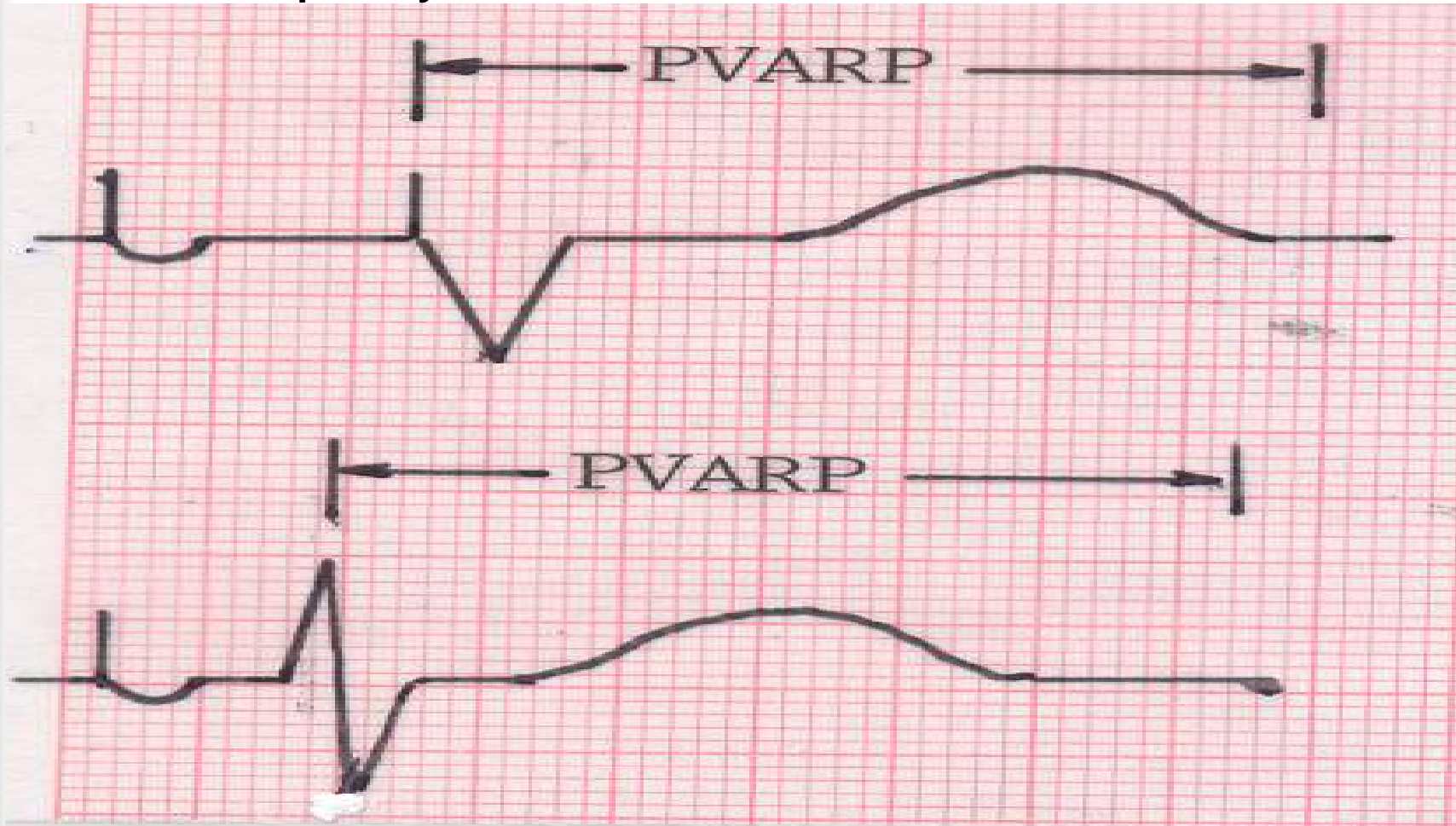
- **Adaptive AV interval** = because heart rate varies with adrenergic tone, AVI (both paced and sensed) will shorten as pacing rate increases.



- **Atrial escape interval (AEI)** = maximum time period that can elapse between the last sensed or paced ventricular event and the next atrial event

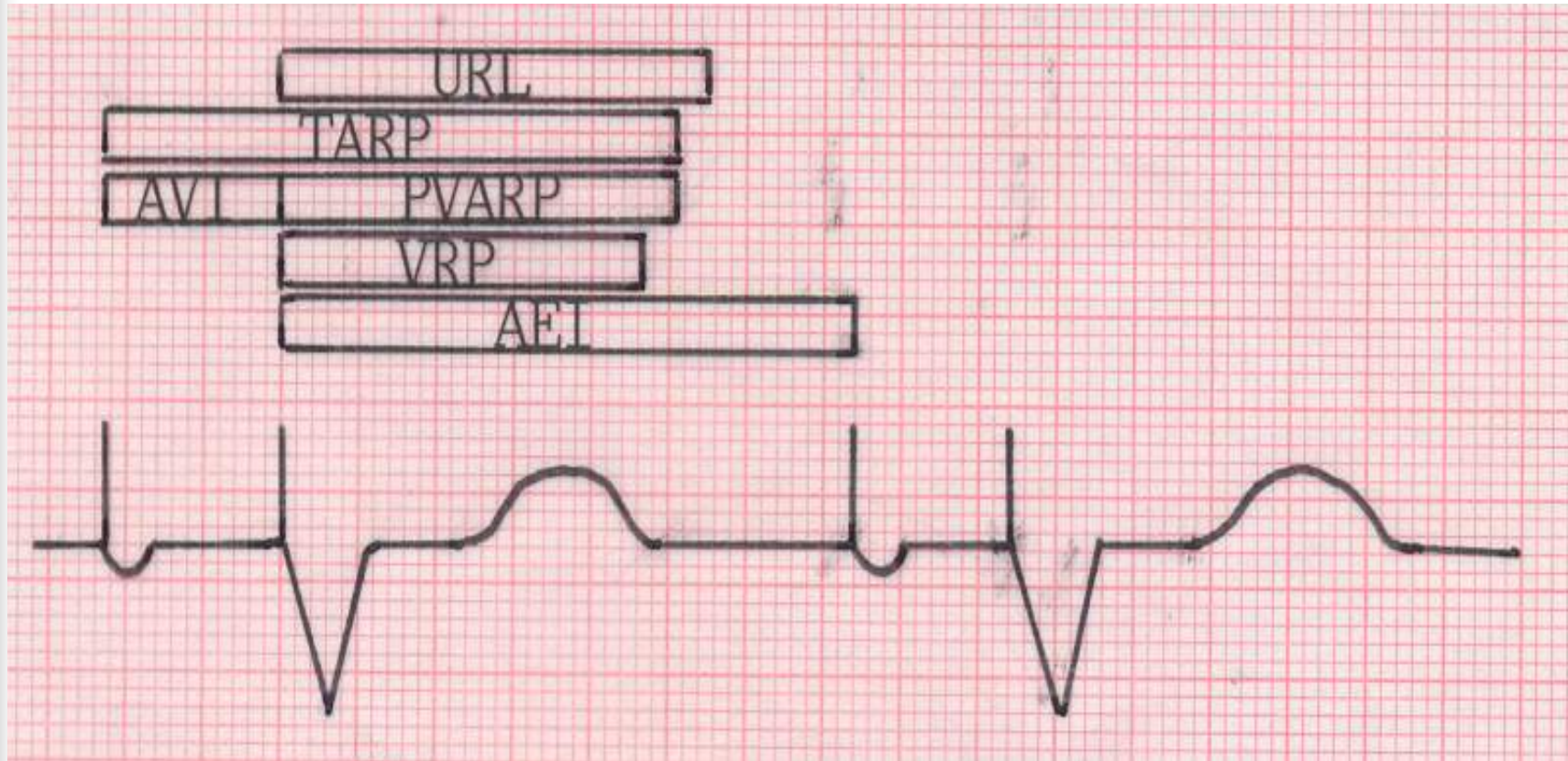


- **Postventricular atrial refractory period (PVARP)** = atrial refractory period following a paced or sensed ventricular event, so as to prevent atrial lead sensing the ventricular depolarization, or sensing retrograde P waves should VPC occur which may induce endless-loop tachycardia



- **Total atrial refractory period, TARP** = AVI + PVARP, which limits upper rate limit of pacemaker
- **Adaptive PVARP** = allow PVARP to shorten with higher pacing rate
- **Upper rate limit (URL)** = maximum tracking rate or interval. A programmable feature (by the programmed TARP) limiting the maximum rate (or shortest interval) at which the pacemaker will allow ventricle to pace

- Ventricular refractory period, VRP, blanking period)
=prevent ventricular sensing the large atrial pulse, therefore inhibit the ventricular output. This problem="crosstalk"
- Relationship between major timing cycles in dual chamber pacing:



■ ***During pacemaker implantation:***

pacing threshold	< 1 V
pulse duration	0.5 ms
impedance: atrium	350-800
ventricle	500-1200

■ ***Once chronic threshold reached:***

pacing output	2.5 V
pulse duration	0.3-0.6 ms
sensitivity: atrium	1.5-2 mV
ventricle	4-5 mV

■ **Complications of pacemaker implantation:-**

bleeding, hematoma, infection, pneumothorax, hemothorax, cardiac perforation, tamponade, air embolism, lead dislodgement, arrhythmias, venous thrombosis etc.

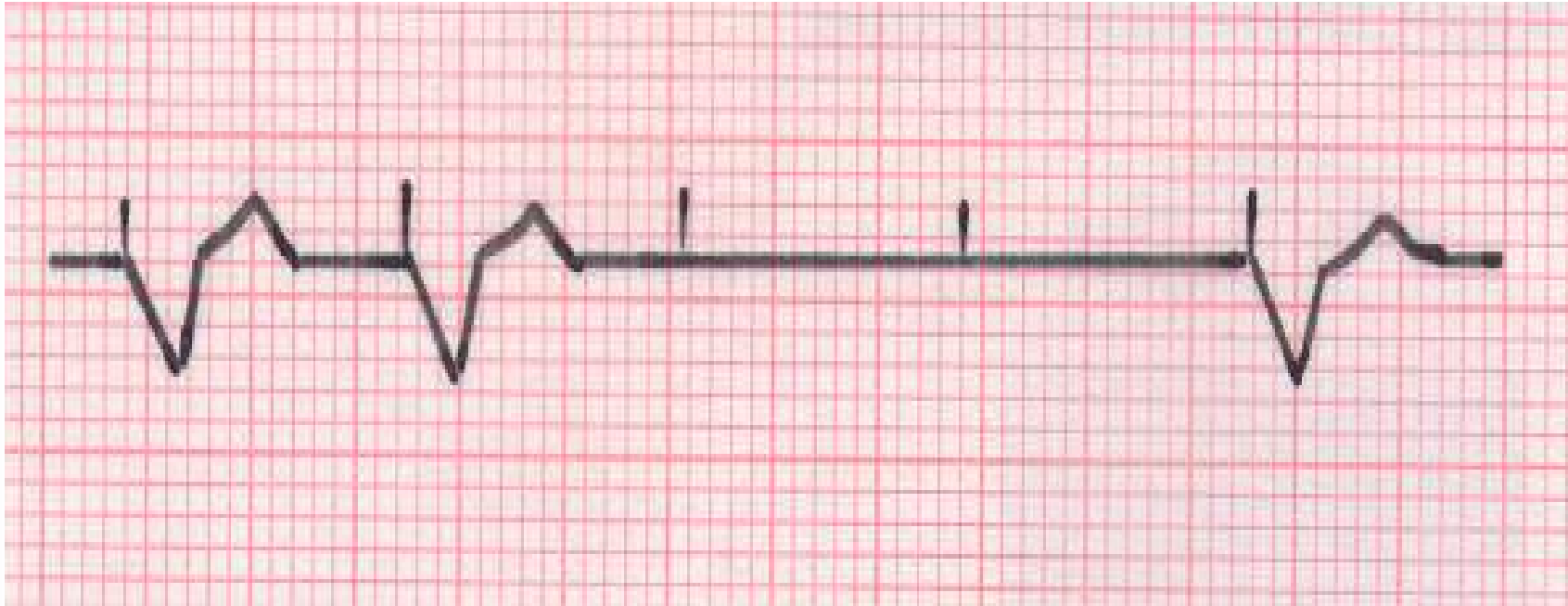
■ **Follow-up of permanent pacemakers:-**

Single chamber pacemaker: twice the first 6 months following implant, then once every year

Dual chamber pacemaker: twice the first 6 months following implant, then once every 6 months

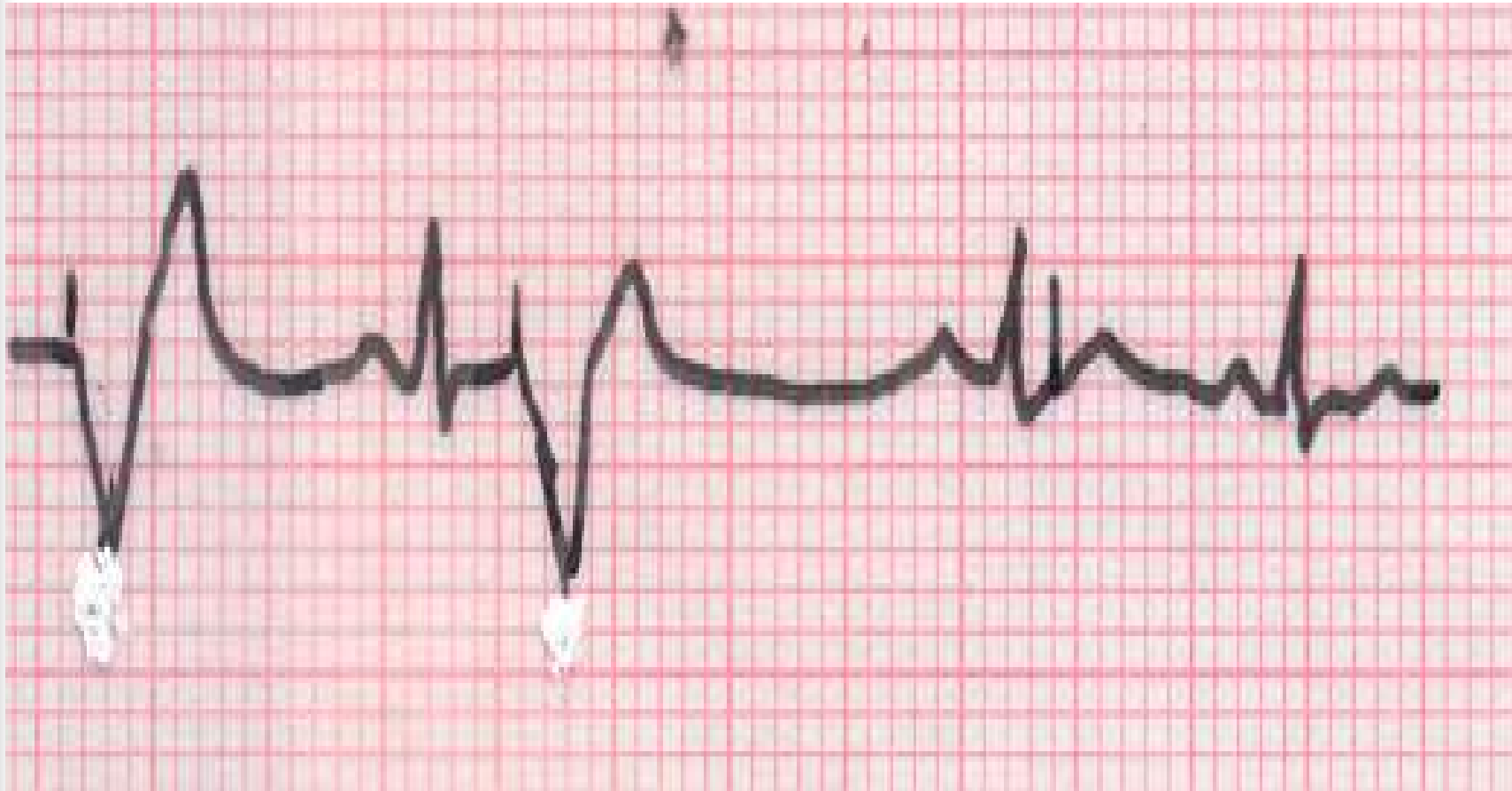
Evaluation of pacemaker malfunction

(1) Noncapture : -



- **Causes:** high capture threshold, inappropriate programming to a low output or pulse width, lead dislodgement, lead insulation failure, loose connection to pacemaker, low battery, severe metabolic imbalance, drug effect, “pseudo-noncapture” (=pacing during refractory period due to undersensing of preceding complex) etc

(2) Undersensing : pacing asynchronously



- **Causes** = poor lead position with poor R or P wave amplitude, lead dislodgement, lead fracture, lead insulation failure, severe metabolic imbalance, myocardial infarction of tissue near electrode, ectopic beats of poor intracardiac amplitude etc.
- **Correction** = increase pacemaker sensitivity

■ **oversensing :-**



- **Causes** = myopotentials, electromagnetic interference, T wave sensing, lead insulation failure, lead fracture, loose fixation screw, crosstalk etc.
- **Correction** = decrease pacemaker sensitivity

- **Pacemaker syndrome :** -
- **Occur in patients with sinus rhythm receiving VVI or dual chamber device where atrial lead not properly pace or sense → loss of atrial contribution to ventricular filling, presence of retrograde AV node conduction, loss of consistent AV synchrony → decrease cardiac output and patient fatigued and uncomfortable whenever pacemaker is pacing.**
- **Correction: For VVI, reduce pacing rate or program hysteresis on to allow more time in sinus rhythm. For dual chamber device → reprogram or correct the lead surgically.**

- **Pacemaker mediated tachycardia (endless loop tachycardia)** : -
- **Premature ventricular beat travels retrogradely up the His bundle, AV node and atrium. If this retrograde P occur after PVARP, the pacemaker (acting as accessory pathway) will sense it and deliver an impulse into the ventricle starting the cycle over and over again.**
- **Correction = appropriate programming of PVARP**

- **Crosstalk** : -
- **Occur when ventricular sensing the large atrial pulse as an intrinsic ventricular beat, and then inhibit the ventricular output. If patients are pacemaker dependent and have no ventricular escape, dangerous asystole occurs.**



- **Correction = program to an appropriate VRP**