Pacemaker Function and Programming

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Goals

• To introduce some basic concepts of pacemaker programming
  - Fixed vs. demand mode
  - Sensitivity
  - Capture
• Case study to illustrate several common features of modern pacemakers
  - Hysteresis
  - Activity Mode
  - Upper Tracking Limit
  - Rest Mode
  - Magnet Response

Modes of Pacing

• Synchronous/Demand
  - DDD, VVI, AAI
  - Delivers a pace only if an intrinsic wave is not detected
• Asynchronous
  - DOO, VOO, AOO, SOO
  - Can be achieved by either
    - Programming
    - Magnet application
  - Cautions:
    - Magnet behavior is programmable in some devices
    - Magnet behavior in a pacemaker is very different from an ICD with an underlying pacemaker
Sensitivity

- Sensitivity
  - Defines the lower amplitude of an intrinsic waveform that is sensed by the device
  - The degree that a pacing system “sees” intrinsic signals
  - Measured in millivolts (mV)

- Sensitivity Threshold
  - The minimum R wave amplitude needed to be detected by the pacemaker
  - Typically the safety margin is set to 2-3 times sensitivity threshold

Sensitivity

- At .15 mV
- At .3 mV

Capture Threshold

- The amount of energy required to consistently capture the heart

- Safety margin
  - Manual: 2:1 or 3:1 safety margin
  - AutoCapture™ pacing systems only from St. Jude Medical
Capture Threshold

- The minimum output pulse needed to consistently capture the heart

3 mA  2 mA  1 mA

Pacemaker Case

- Consulted by a colleague in the PACU
  - 78 yo female, 5’4”, 55 kg with PVD and critical limb ischemia for emergent vascular intervention.
  - Pt has implanted device in chest

- Device placed several years ago, unclear indication, bradycardia?
  - Pt does not recall last interrogation or device manufacturer.
  - Seen by her cardiologist 8 months ago, ‘everything is fine’
Pacemaker Case

- Likely: 2-chamber pacing
  - DDD
  - Does not appear to be pacemaker dependent

- External pacer/defibrillator
- Magnet
Pacemaker Case - Induction

- Pre-induction on monitors
  - EKG shows As-Vs, rate of 72

- Following Induction
  - HR dips to 65 → 60 → 55 → 50
  - Pacing initiated at 60 bpm; Ap-Vp on EKG

Pacemaker Case - Hysteresis

- Ap-Vp: Lower rate limit (LRL) is 60 bpm, but only starts after sensed rate falls below 50

- Hysteresis
  - Following Vs - uses hysteresis rate 50 ppm (1200 ms)
  - Following Vp – pace at 60 ppm (1000ms)
Pacemaker Case - Surgical prep

- Surgical prep
  - HR increases to 90 bpm
  - EKG shows \( \rightarrow \) Ap-Vp

- LRL increased to 90
- Sensor in the device interprets mechanical motion during prep as physical activity \( \rightarrow \) Pacing rate increases to 90 bpm

- Rate responsiveness or Adaptive-rate pacing

Rate responsiveness or Adaptive-rate pacing

- In Rate Responsive pacing (modes ending with "R"), sensor(s) in pacemaker are used to detect changes in physiologic needs and increase the pacing rate accordingly
Pacemaker Case - Incision

- As-Vp at 70
- Incision is followed by increased HR
  - As-Vp at 70 → 90 → 110
  - Irregular HR at ~105 bpm

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Pacemaker Case - Incision

- Pulse rate drops to ~80 bpm . . .

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Pacemaker Case - Incision

- As-Vp Wenckebach
- As-Vp 2:1 block
Upper Rate Limit Behavior – Pacemaker Wenckebach

- Maximum tracking rate (MTR)
  - 120 bpm = 500 ms cycle
  - If atrial rate is ~133 bpm = 450 ms cycle
  - PV delay is extended to maintain 500 ms ventricular cycle

- PV delay extends, V-A interval decreases until next P wave falls within PVARP (post ventricular atrial refractory period)
- Atrial event is ignored → no ventricular stimulus is triggered
Upper Rate Limit Behavior – Multiblock

- 2:1 or 3:1 conduction due to high atrial rate
- Every other P wave occurs during atrial refractory period

Upper Rate Limit Behavior – Multiblock

Intrinsic Atrial rate
160 bpm

3/4ms (A-A)

Paced Ventricular Rate
2:1 Block: 80 bpm
750 ms (V-V)

Upper Rate Limit Behavior

- Upper Rate Limit = Speed limit
  - Wenckebach permits rapid ventricular rates close to URL
  - Multiblock limits rate but reduces rate by 50% or greater

- Appropriate behavior
- Avoids pacing at uncomfortable or unsafe rates
Pacemaker Case – Operative period

- Limited surgical stimulation
  - HR decreases
  - Ap-Vs: Pacing is initiated at 60 bpm

- 20 minutes later, rate drops to 50 bpm
  - EKG shows Ap-Vs
- Rate resumes at 60 (Ap-Vs) after 4 min
- Periodically drops to 50 bpm

Operative Period

- Ap-Vs: Fluctuating Lower Rate Limit

Rest Rate Feature

- Identifies periods of low activity → lower metabolic need
- Lower HR needed
- Activity sensor or time of day determines period of sleep
Pacemaker Case - Magnet Applied

- Ap-Vs at 50 bpm
- Magnet is placed over device
- No change
- Typical Magnet Behavior: Asynchronous pacing (DOO, VOO, AOO)

Magnet Response

- Pacemaker is unresponsive to magnet
- Magnet response is programmed off

Summary

- Rate responsiveness or Adaptive-rate pacing
- Upper Rate Limit Behavior
  - Pacemaker Wenckebach
  - Multiblock
- Lower Rate Limit Behavior
  - Hysteresis
  - Rest rate/Sleep mode
- Programmable Magnet Response
Conclusions

- Inappropriate features may be disabled
  - Activity sensor
  - Rest rate
- Hysteresis & Upper rate limit
- Verify magnet response on