Advanced Timing Cycles
Advanced timing cycles

Objectives

Upon completion of this program the participant will be able to:

- Identify timing cycles of single-chamber (VVI/AAI), dual-chamber (DDD), and adaptive-rate pacemakers.
- Explain the significance of TARP and calculate TARP based on given parameters.
- Describe upper rate pacing characteristics of 1:1 conduction, pacemaker Wenckebach and 2:1 block
- Describe the difference in atrial- and ventricular-based timing systems.
Timing cycles

- Single chamber
- Dual chamber
- Timing systems
Single-chamber Timing Review
Single chamber

Timing Intervals

Interval (ms) = 60,000 / rate (ppm)

60,000 / 60 ppm = 1000 ms
Single chamber

VVI

VP VP VS VP

V Ref V Ref V Ref V Ref

V-V Automatic Interval Escape Interval
Single chamber

AAI

AP  PVC  AP  AS  AP

A  Ref
A-A

Automatic Interval  Escape Interval
Sensor-determined Rate Controls V-V Interval

LRL

VRef

MSR
Shortened Sensing Windows at High Rates
Dual-chamber Timing Review
Timing intervals

Dual chamber (DDD)

- V-V = Lower Rate Limit
- VA = Atrial Escape Interval
- AV = AV Delay

\[ V-V = VA + AV \]
Example

\[ V-V = VA + AV \]
\[ VA = V-V - AV \]

Lower Rate = 60 ppm  \hspace{1cm} V-V = 1000 ms
AV Delay = 200 ms

\[ VA = 1000 \text{ ms} - 200 \text{ ms} = 800 \text{ ms} \]
AV sequential pacing

A Pace / V Pace

AV Delay

VA Interval

LRL
Atrial pacing with conduction

A Pace / V Sense

AV Delay

VA Interval

LRL
P-synchronous pacing

A Sense / V Pace

AV Delay

VA Interval

LRL

MTR
Complete inhibition

A Sense / V Sense

AV Delay

VA Interval

LRL
Timing intervals

Dual chamber (DDD)

- AV Delay
- V-Blanking
- PVARP
- A-Blanking
- VA Interval
- V Ref
- MTR
- LRL
Timing intervals

DDI Mode - Review of PVARP

- Provides AV sequential pacing at the lower rate with dual-chamber sensing
- Prevents competitive atrial pacing
- Atrial refractory period is added to prevent oversensing
- PVARP is an atrial refractory period that occurs after a paced or sensed ventricular event
- Prevents the atrial channel from sensing the ventricular pacing pulse, the far-field QRS and retrograde P-waves
DDI mode

- Adds PVARP
  - DDI
    - PVARP
  - DVI
    - AV Delay
  - VVI
    - Refractory
  - VOO
    - 1000 ms (60 ppm)
Maximum tracking rate operation

PVARP and TARP

\[ TARP = AV + PVARP \]

2:1 Rate = 60,000 / TARP
Maximum tracking rate operation

Pacemaker Wenckebach

AS       VP

AV

PVARP

TARP

Maximum Tracking Rate

AS       VP

AV  W

PVARP

TARP
Maximum tracking rate operation

4:3 Wenckebach

AS VP AS VP AS VP (AS) AS VP AS VP AS VP

TARP

AV Delay

VA Interval

MTR
Maximum tracking rate operation

2:1 Block

2:1 Rate = 60,000 / TARP
Maximum tracking rate operation

2:1 Block

AS VP (AS) AS VP (AS) AS VP (AS) As Vp (AS)

TARP

AV Delay

VA Interval

MTR

LRL
Maximum tracking rate operation

Sinus Rate

2:1 Block

Wenckebach

1:1

Upper rate behavior is determined by TARP and MTR
Maximum tracking rate operation

2:1 Block > MTR

MTR = 140 ppm
AV = 100 ms
PVARP = 300 ms
TARP = 400 ms

2:1 Block Point
= 60,000/TARP
= 60,000/400
= 150 bpm

Sinus Rate

Wenckebach

1:1

TARP
MTR
LRL
Maximum tracking rate operation

2:1 Block < MTR

MTR = 140 ppm
AV = 200 ms
PVARP = 300 ms
TARP = 500 ms

2:1 Block Point
= 60,000/TARP
= 60,000/500
= 120 bpm
Sensor pacing

Sensor Rate Controls the VA Interval

Lower Rate
60 ppm

Sensor Pacing
110 ppm
Sensor-controlled Rate Not Limited by PVARP

Sensor Pacing 150 ppm
Sensor-driven (DDDR) pacing promotes a more regular rhythm if the sinus rate exceeds the MTR.
Pacemaker mediated tachycardia (PMT)
Program longer PVARP
  • PVARP after PVC

Use PMT prevention scheme
DDDR: sinus or sensor?

Follow the Faster Input
Dynamic AV Delay

- Programmed AV Delay shortens with increasing rate
- Uses discrete steps or linear reduction
- Allows a higher 1:1 P-synchronous tracking rate
Dynamic AV Delay

Rate = 65 ppm
AV Delay ~180 ms

Rate ↑ to 135 ppm
AV Delay ↓ to ~ 80 ms
### Dynamic AV Delay

#### Effects of Shorter AV Delay

<table>
<thead>
<tr>
<th>AV DELAY</th>
<th>PVARP</th>
<th>TARP</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 ms</td>
<td>300 ms</td>
<td>365 ms (164 ppm)</td>
</tr>
<tr>
<td>130 ms</td>
<td>300 ms</td>
<td>430 ms (139 ppm)</td>
</tr>
<tr>
<td>200 ms</td>
<td>300 ms</td>
<td>500 ms (120 ppm)</td>
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</tbody>
</table>
Timing Systems
Ventricular- and atrial-based timing

Ventricular-Based Timing: Ventricular events start timing cycles

Atrial-Based Timing: Atrial events start timing cycles
Timing systems

LRL Behavior with AV Conduction

LRL = 1000 ms (60 ppm)
AV Delay = 200 ms
VA Interval = 800 ms
PR Interval = 150 ms

Pacing Interval = VA + PR = 950 ms
Atrial pacing = 63 ppm
Effective ventricular rate = 63 bpm

Pacing Interval = AV + VA = 1000 ms
Atrial pacing = 60 ppm
Effective ventricular rate = 60 bpm
Timing systems

LRL Behavior with Intermittent AV Conduction

LRL= 1000 ms (60ppm)
AV Delay = 200 ms
VA Interval = 800 ms
PR Interval = 150 ms

Pacing Interval = 950 or 1000 ms
Atrial pacing at 63 or 60 ppm
Effective ventricular rate = 63 or 60 ppm

Pacing Interval = A-A Interval = 1000 ms
Atrial pacing at 60 ppm
Effective ventricular rate = 63 or 57 ppm
Timing systems

LRL Behavior with AV Sequential Pacing (AP + VP)

LRL = 1000 ms (60 ppm)
AV Delay = 200 ms
VA Interval = 800 ms

Pacing Interval = 1000 ms
Atrial pacing at 60 ppm
Effective ventricular rate = 60 ppm
Timing systems

MSR Behavior with AV Conduction

**Ventricular Timing**
- MSR = 400 ms (150 ppm)
- AV Delay = 200 ms
- VA Interval = 200 ms
- PR Interval = 150 ms
- Pacing Interval = VA + PR = 350 ms
- Effective ventricular rate = 171 bpm

**Atrial Timing**
- Pacing Interval = AV + VA = 400 ms
- Atrial pacing = 150 ppm
- Effective ventricular rate = 150 bpm
Summary

**Single-Chamber Timing**
- VVI & AAI
- VVIR

**Dual-Chamber Timing**
- DDD & DDI (brief review)
- Upper rate behavior
- DDDR
- Dynamic AV Delay

**Timing Systems**
- Ventricular- and Atrial-based timing
Questions?
Advanced Timing Cycles