Pacing and ICD Considerations in Cardiac Rehab

Kimberly Dail, BSN, RN, CV-BC, CCRP

WakeMed Cary Cardiac Rehab

kdail@wakemed.org

919.350.1995

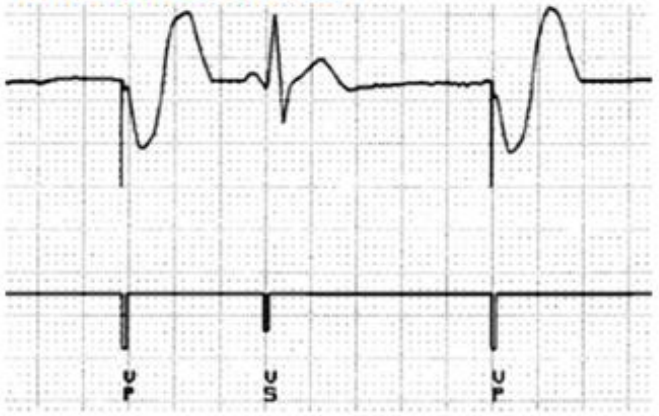
Objectives

- Explain different types of pacemakers, ICDs and the NBG Code
- Describe indications for PPMs and ICDs
- Explain basic pacing and ICD functions
- Identify paced rhythms
- Explain timing intervals in pacemakers and ICDs
- Describe upper rate behavior
- Explain chronotropic incompetence and how devices assist in exercising patients
- Describe necessary requested device parameters/settings in the cardiac rehab patient
- Describe the detection zones and parameters used to identify a tachyarrhythmia
- Explain the use of CRT-P and CRT-D therapies in Heart Failure patients

SINGLE CHAMBER SYSTEM

- One lead
  - Atrium
  - Ventricle (most common)
- May be used for patients in chronic AF (VVI pacemaker) or patients with sinus node dysfunction and no history of AV block (AAI pacemaker)

VVI Pacemaker



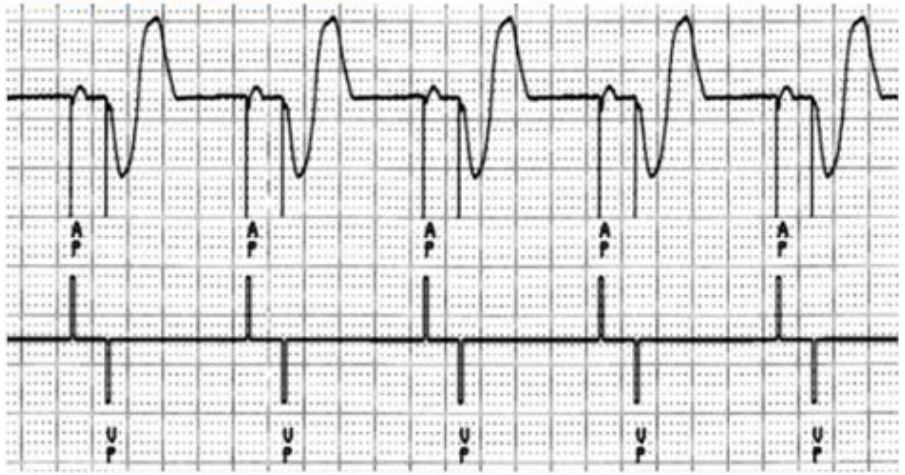
AAI Pacemaker

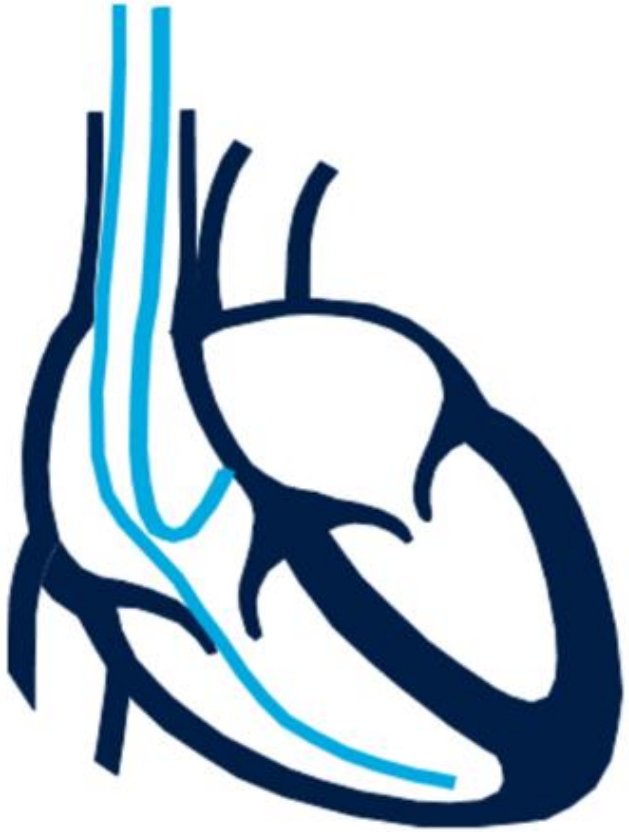
Source: Medtronic Academy

DUAL CHAMBER SYSTEM

- Two leads
  - One lead implanted in the atrium
  - One lead implanted in the ventricle
- Provides AV synchrony and pacing support in both atrium and ventricle if needed

DDD Pacemaker



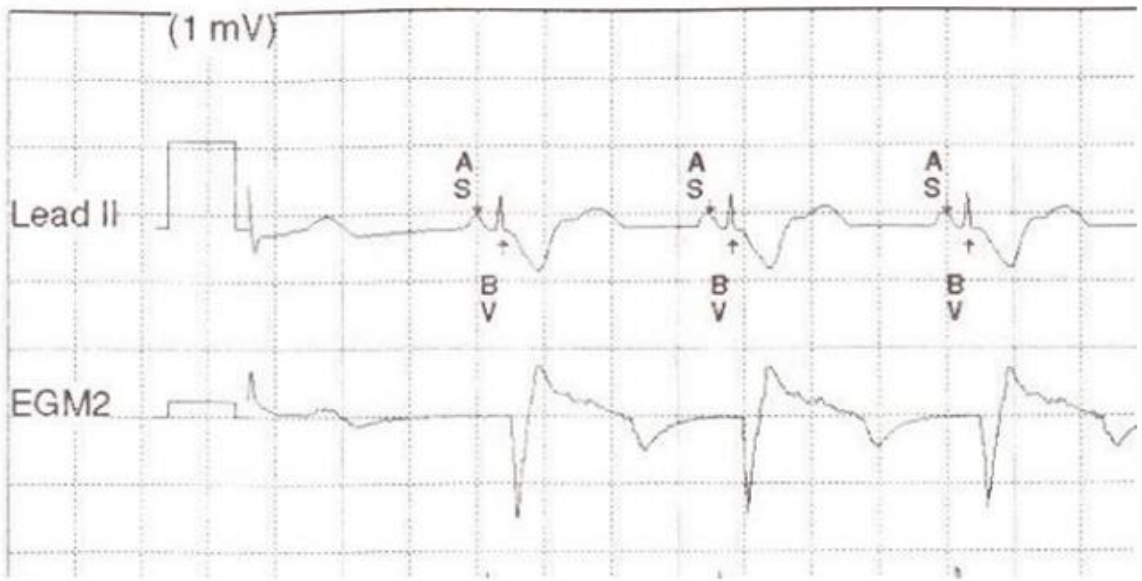


Source: Medtronic Academy

TRIPLE CHAMBER SYSTEM

- Three Leads:
  - Right Atrium
  - Right Ventricle
  - Left Ventricle (via the Coronary Sinus vein)
- Most commonly called a Bi-Ventricular Pacemaker but also called Cardiac Resynchronization Therapy (CRT–P)
- Paces both ventricles together to "resynchronize" the beat

DDD BiV Pacemaker



Source: Medtronic Academy

Indications

Pacemakers	ICDs	CRT
• Sinus Node Dysfunction • Symptomatic Chronotropic Incompetence • AV Block • Atrial Fibrillation	• Surviving Cardiac Arrest d/t VF or VT • Spontaneous VT • ICM AND NICM with EF ≤35%	• Symptomatic HF with LVEF ≤35%, QRS >120->150ms and LBBB

Post-Implant and Exercise

Common Restrictions

Keep affected arm/shoulder below shoulder level x ~4 weeks	No lifting > 5 lbs x ~ 4 weeks	Infection monitoring Infection rate is ~ 1% Most occur in the 1st month after implant

NBG Code

- The NBG code is a lettered code that describes the basic function of pacing devices
- Tells us which chamber(s) is being paced and sensed
- Most common modes programmed:

DDD = Dual Chamber Pacing and Sensing

VVI = Single Chamber Pacing and Sensing (Ventricle Only)

AAIR-DDDR = Paces AAI/R with DDD back-up to allow for intrinsic conduction as much as possible

"R" = Rate Response

NBG CODE – THE USUAL PACING MODES

Disregard/Not usually seen

Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing	Rate Modulation	Multisite Pacing
O = None	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	T = Triggered	R = Rate modulation	A = Atrium
V = Ventricle	V = Ventricle	I = Inhibited		V = Ventricle
D = Dual (A +V)	D = Dual (A + V)	D = Dual (T + I)		D = Dual (A + V)
S = Single (A or V)	S = Single (A or V)			

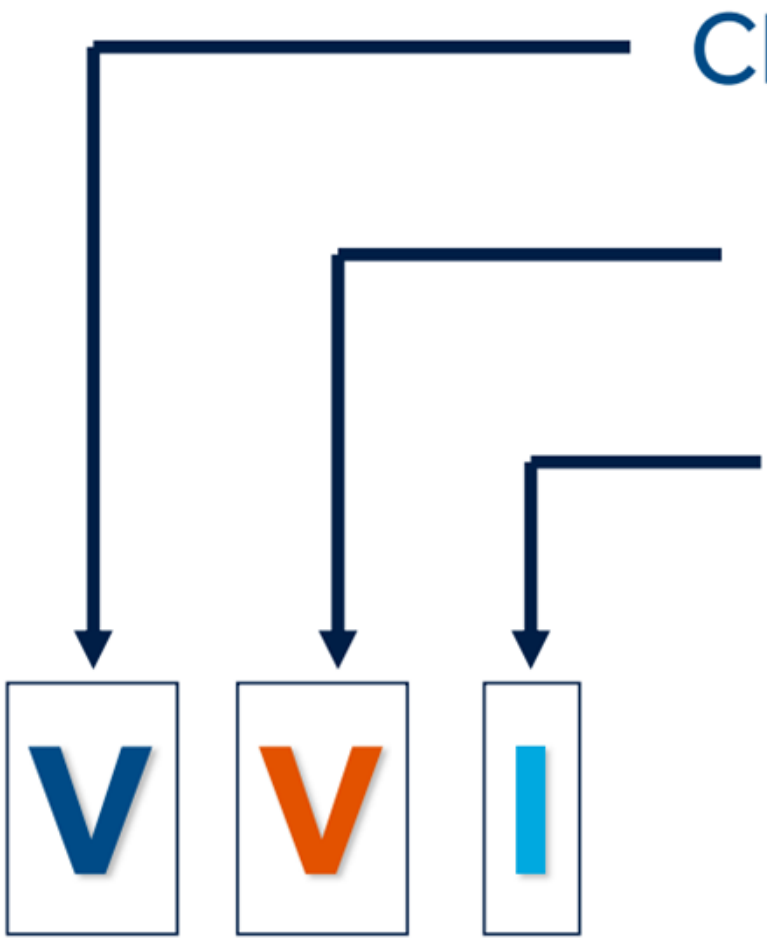
Examples of pacing modes which are typically programmed:

DDD **VVI** **DDIR** ⇨ Used for AFib; non-tracking mode

DDDR **VVIR** **AAIR**

Source: Medtronic Academy

3 BASIC LETTERS & WHAT THEY STAND FOR



Chamber that's paced

Chamber that's sensed

What to do in response to a sensed beat

A ventricular sense inhibits the next scheduled ventricular pace

Source: Medtronic Academy

"R" means "Rate response"

Pacemaker will increase pacing rate in response to exercise – if patient does not increase his own rate

Source: Medtronic Academy

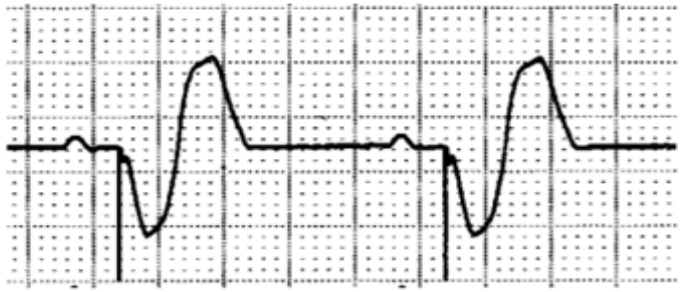
Knowledge Check

- **DDDR**
  - What chamber is being paced?
  - What chamber is being sensed?
  - What happens when a chamber is sensed?
  - Is Rate Response on?
- **VVIR**
  - What chamber is being paced?
  - What chamber is being sensed?
  - What happens when a chamber is sensed?
  - Is Rate Response on?

KNOWLEDGE CHECKPOINT

Label each EKG with the faces of pacing (AS-VS, AP-VS, AP-VP, AS-VP).

A



B

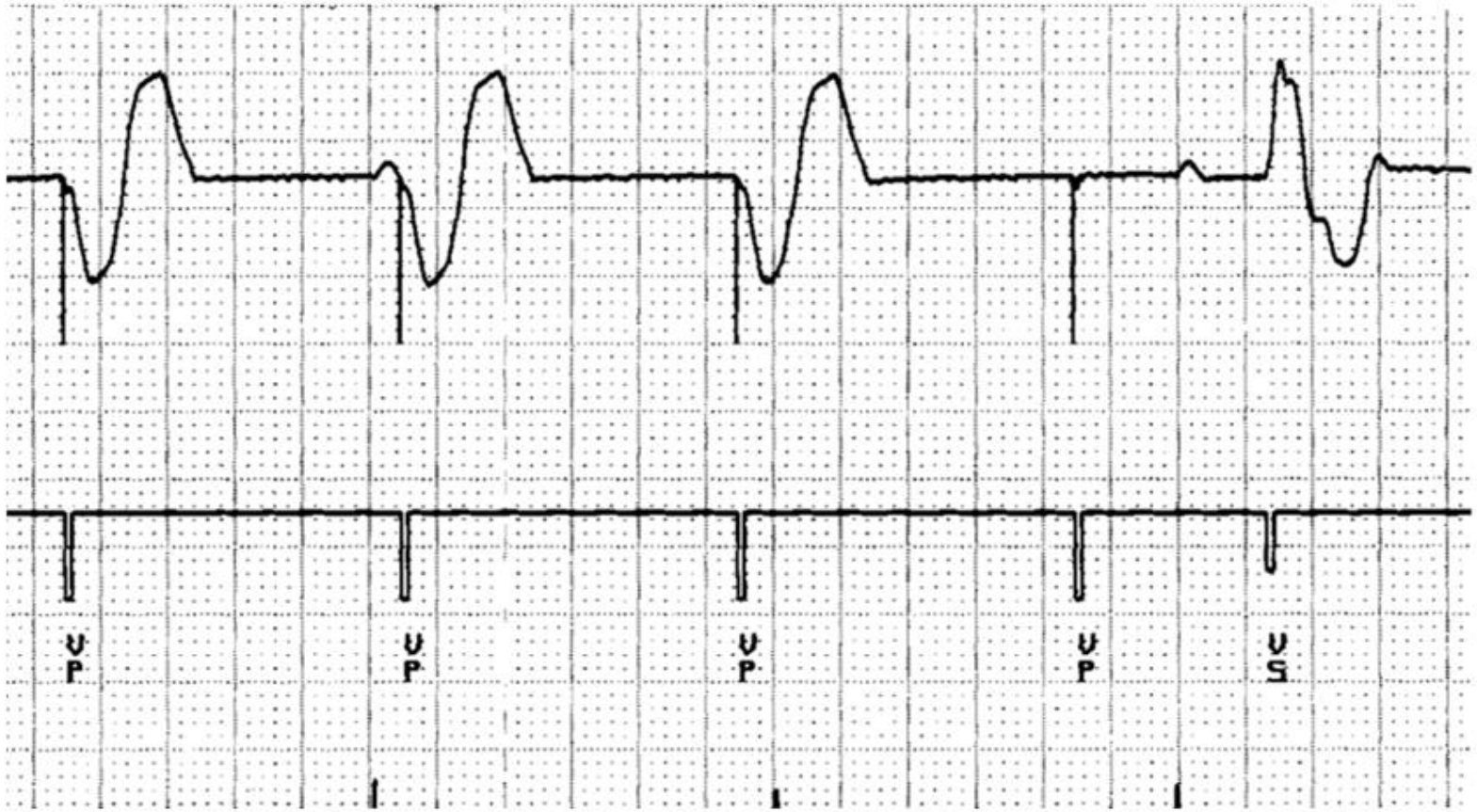
C

D

Source: Medtronic Academy

CAPTURE THRESHOLD

The minimum electrical stimulus needed to consistently capture the heart outside of the heart's own refractory period



Ventricular pacemaker 60 ppm

Source: Medtronic Academy

FACTORS THAT CAN AFFECT THRESHOLDS

- Pacemaker circuit (lead) integrity
  - Insulation break
  - Wire fracture
- The characteristics of the electrode
- Electrode placement within the heart
- Drugs
- Electrolytes
- Sleeping/Eating

Hayes DL, Asirvatham SJ, Friedman PA. *Cardiac Pacing, Defibrillation, and Resynchronization.* Hoboken, NJ: Wiley-Blackwell; 2010.

Timing Cycles

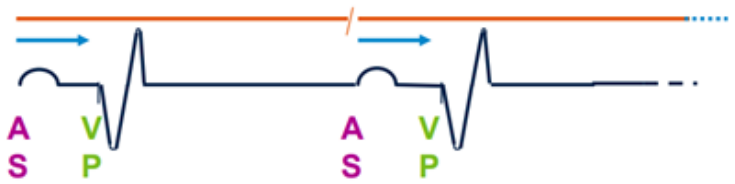
PPMs and ICDs are a bunch of “clocks” with timers

Every paced or native beat starts a new clock

- **Lower Rate (LR)** = the lowest rate allowed by the device
- **Sensed AV (SAV)** = the timer starting from a sensed atrial beat
- **Paced AV (PAV)** = the timer starting from a paced atrial beat
- **Upper Tracking Rate (UTR)** = the fastest rate a device will track the atrium
- **Upper Sensor Rate (USR)** = the fastest rate a device will allow the sensor to pace

DDD EXAMPLES CONTINUED
THE FOUR FACES OF DDD

3. Atrial sensing, ventricular pacing



An AS (P-wave) inhibits lower rate timer and triggers an AV delay timer (SAV)

- SAV expires without being inhibited by a VS, resulting in a VP

4. Atrial and ventricular sensing

An AS (P-wave) inhibits lower rate timer and triggers an AV delay timer (SAV)

- Before the SAV can expire, it is inhibited by a VS (R-wave)

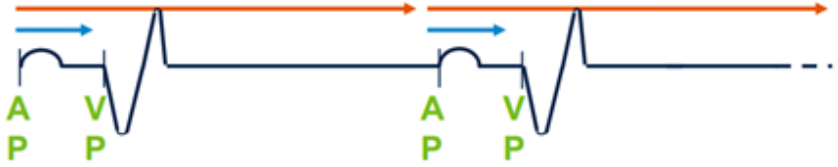
Remember:

Every beat triggers a new timer

The PPM cannot violate timers!

DDD EXAMPLES
THE FOUR FACES OF DDD

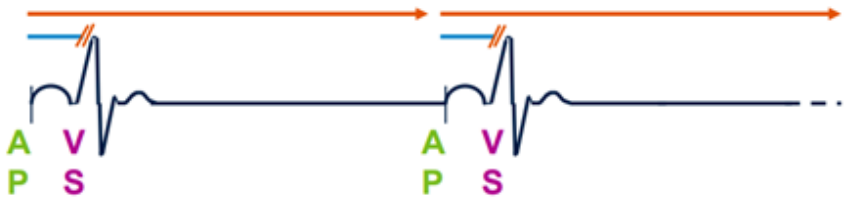
1. Atrial and ventricular pacing



AP re-starts lower rate timer and triggers an AV delay timer (PAV)

- PAV expires without being inhibited by a VS, resulting in a VP

2. Atrial pacing, ventricular sensing



AP restarts lower rate timer and triggers an AV delay timer (PAV)

- Before PAV can expire, it is inhibited by a VS (R-wave)

Source: Medtronic Academy

Upper Rate Behavior – Help Us!

Upper Tracking Rate (UTR)

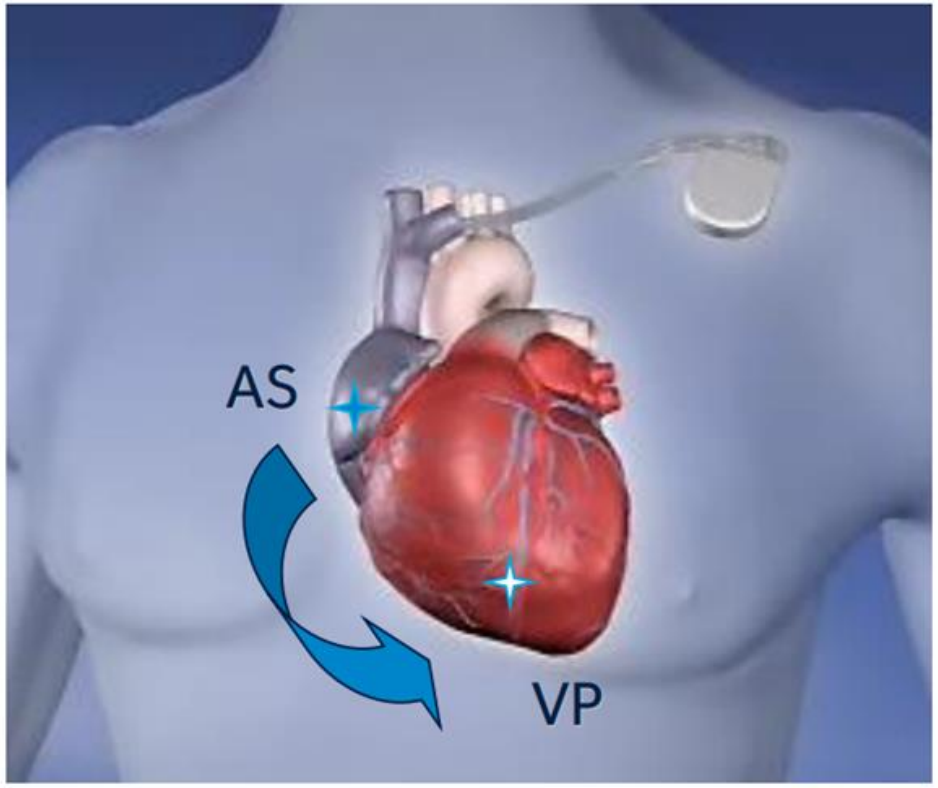
- The fastest heart rate the pacemaker will track the atrium – 1:1 AV Synchrony
- This is programmable
- Should be programmed "just above the maximum sinus rate reached during exercise" to allow for 1:1 conduction and prevent Wenkebach and 2:1 AV Block

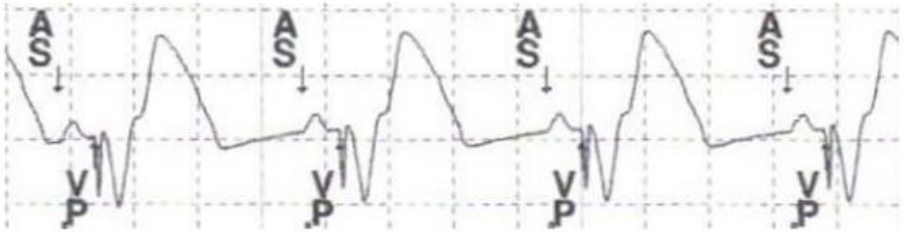
Upper Sensor Rate (USR)

- Is the upper sensor-driven rate limit reached during vigorous exercise
- This is programmable
- Is usually programmed to 85% of the age-predicted maximum heart rate (220 – age in years)

UPPER TRACKING RATE

IN DDD & VDD MODES THE PACEMAKER WILL "TRACK" THE ATRIUM





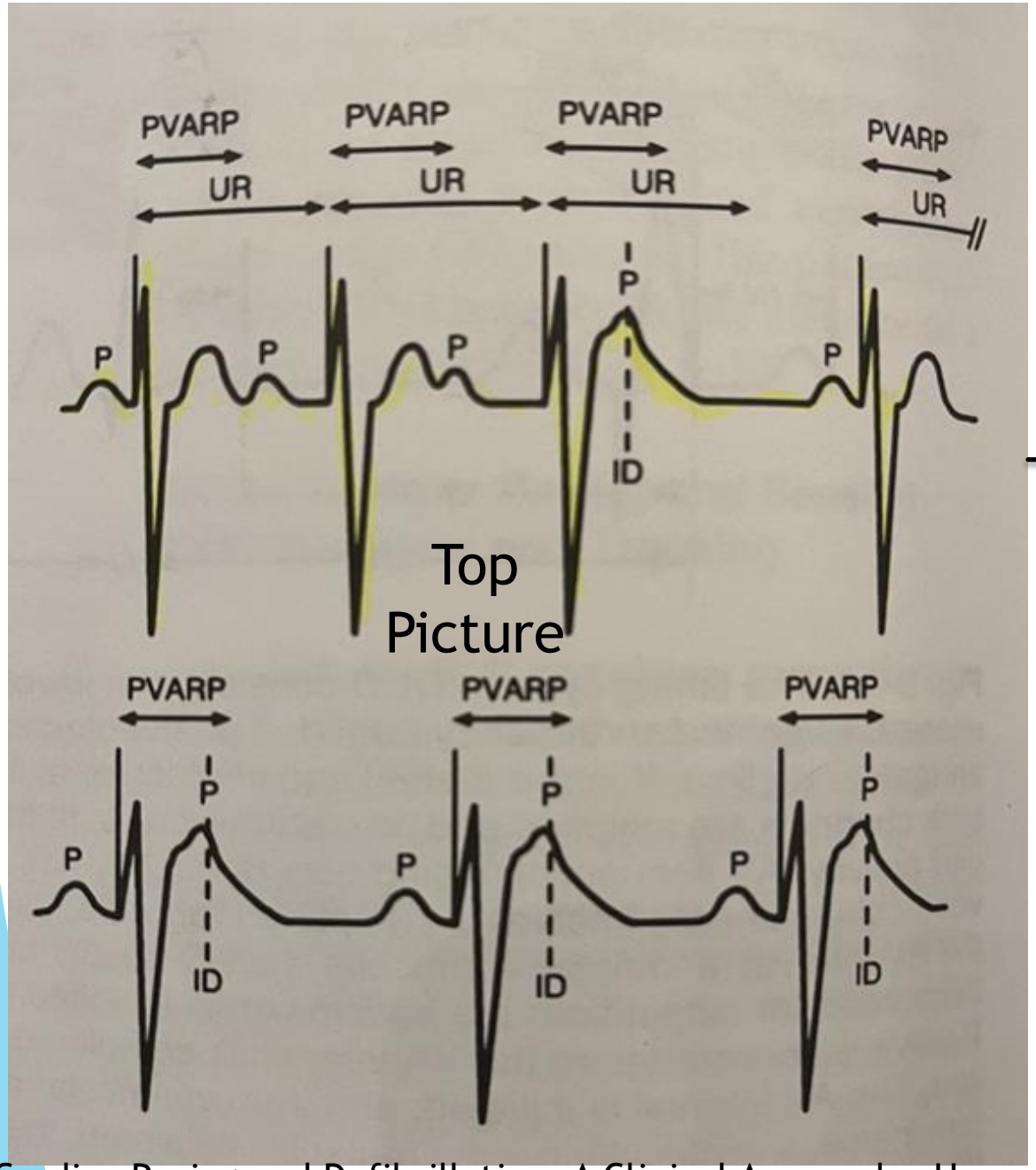
Tracking = Pacing the ventricle after an atrial intrinsic event

Maintains AV Synchrony

Want to limit how fast we pace

The GOAL is to maintain AV Synchrony at all times

Source: Medtronic Academy



Cardiac Pacing and Defibrillation: A Clinical Approach. Hayes, Lloyd, Friedman 2000

When the sinus rate exceeds the programmed maximum tracking rate (UTR), several upper rate behaviors can occur:

1. First, Wenkebach may occur
2. Then 2:1 AV Block can occur

Top picture:

*Wenkebach occurs

*The PPM cannot violate the UTR timing cycle!

Bottom picture:

*2:1 AV Block

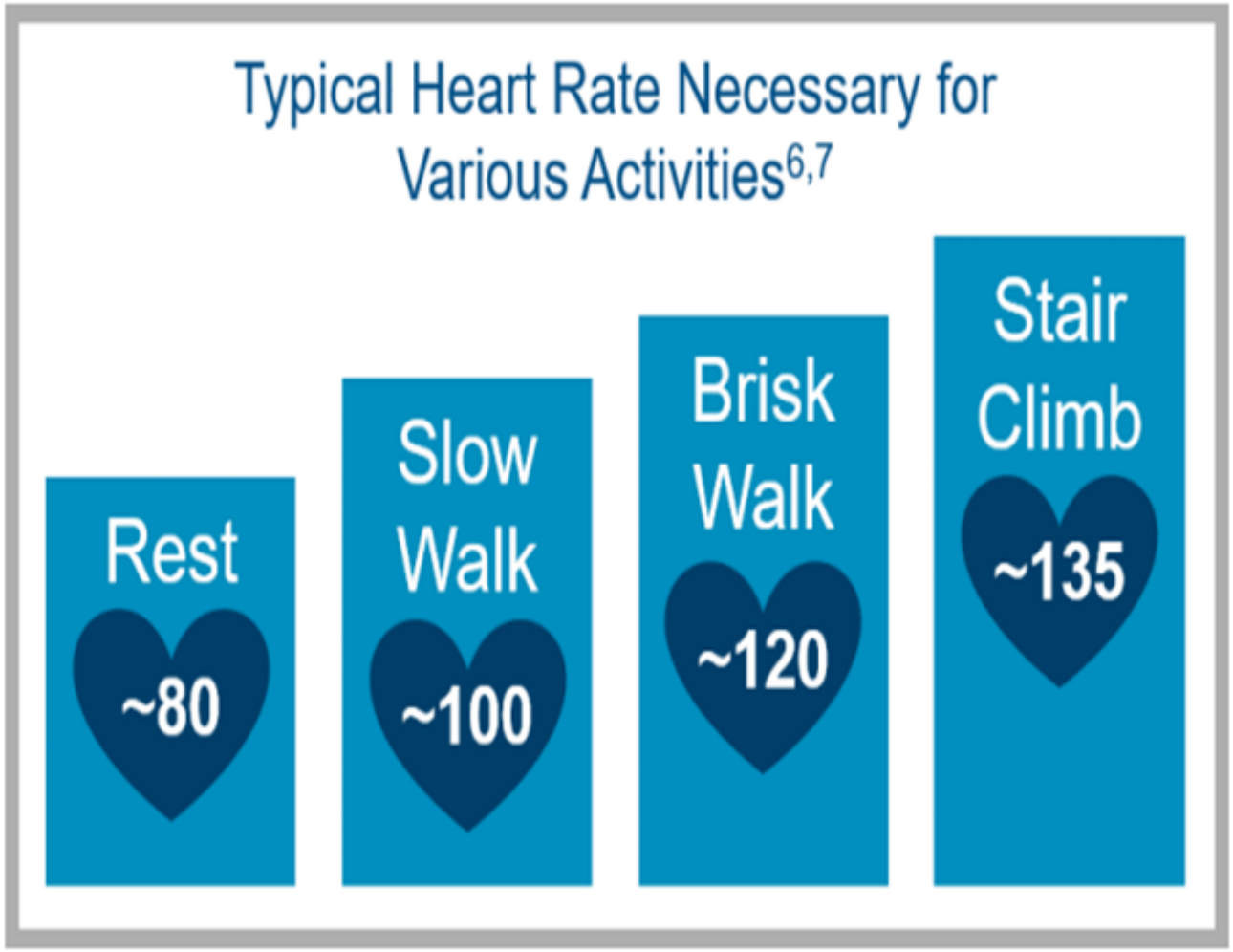
*Every other sinus beat falls into the PPM's refractory period and "is not seen"

*Heart Rate falls by half

Chronotropic Incompetence (CI)

- The inability of the heart rate to increase appropriately in response to an increase in activity or metabolic demand.
- CI is common in various types of cardiac disease including sick sinus syndrome, atrioventricular (AV) block, coronary artery disease, and heart failure. It can also occur in patients with no structural heart disease.
- CI produces exercise intolerance that impairs quality of life, and is an independent predictor of major adverse cardiovascular events and overall mortality
- During maximal aerobic exercise in healthy humans, V_{O_2} increases approximately 4-fold. This is achieved by a 2.2-fold increase in heart rate.
- **Thus, the increase in HR is the strongest contributor to the ability to perform sustained aerobic exercise.**

Circulation. Chronotropic Incompetence: *Causes, Consequences, and Management.* *Pete*
H. Brubaker and Dalane W. Kitzman. 8Mar 2011



- Numerous studies have shown the prevalence of CI is roughly 45% for heart failure patients, and approximately 70% for CRT patients.
- The causes of CI may include medication, not exercising, or compromised heart function.

Source: Boston Scientific CRM-569208-AA; Right Rate Sensor

Rate Adaptive Pacing Sensor Types

- There are typically 2 types of rate adaptive pacing sensors: accelerometer-based sensors and respiration-based sensors.
- Blended sensors combine both sensor types.

Accelerometer-Based Sensors

- • Most devices have a motion-based accelerometer sensor.
- • Rate response is proportional to motion.

Respiration-Based Sensors

- • Boston Scientific's RightRate™ is a physiologic minute ventilation sensor.
- • Rate response is highly correlated with breathing.

Source: Boston Scientific CRM-569208-AA; Right Rate Sensor

Rate Adaptive Pacing Sensors

A motion-based sensor may not always detect when the patient is exercising or being active, potentially resulting in inadequate rate response for activities such as:

- Riding a bicycle
- Holding a grandchild
- Carrying groceries
- Working in the garden
- Using a walker
- Swimming
- Lifting weights

Key Take-Aways

- Be On Alert for Chronotropic Incompetence
- Know if Rate Response is programmed ON/OFF
- Pacemaker configuration and programming can influence exercise capacity

Sources: 1. Boston Scientific CRM-569208-AA; Right Rate Sensor
2. AACVPR Guidelines for Cardiac Rehabilitation Programs 2021

SUDDEN CARDIAC ARREST
IMPLANTABLE CARDIAC DEFIBRILLATORS

- Implantable cardiac defibrillators (ICDs) treat abnormal heart rhythms (ventricular arrhythmias) such as ventricular tachycardia and ventricular fibrillation.
- These life-threatening rhythms can cause sudden cardiac arrest (SCA), which results in death if not treated.
- 98% of people survive a lethal arrhythmia when treated with defibrillation.[1] Only 5% of people survive SCA without defibrillation.[2]

[1] Glikson M, Friedman PA. The implantable cardioverter defibrillator. *Lancet*. April 7, 2001;357(9262):1107-1117.
[2] Epstein AE, DiMarco JP, Ellenbogen KA, et al. ACC/AHA/HRS 2008 Guidelines for device-based therapy of cardiac rhythm abnormalities [corrections appear at *J Am Coll Cardiol*. April 21, 2009; 53(16):1473. *J Am Coll Cardiol*. January 6, 2009;53(1):147]. *J Am Coll Cardiol*. May 27, 2008;51(21):e1-62.

MAJOR FUNCTIONS OF AN ICD

- Sense appropriate cardiac signals
- Detect dangerous rhythms reliably
- Provide pacing and defibrillation therapy
- Store diagnostics

Source: Medtronic Academy

ICD Detection and Therapies

Detection		Interval (Rate)	Initial	Therapies...
VF	On	320 ms (188 bpm)	24/32	ATP During Charging, 35J x 6
FVT	OFF	240 ms (250 bpm)		All Rx Off
VT	OFF	360 ms (167 bpm)	16	All Rx Off
Detection (V.)...		VT Monitor, AF/Afl, Sinus Tach, Wavelet, TWave, Noise(Timeout)		

- Three detection zones and a monitor zone available
  - VF zone
  - Fast VT zone
  - VT zone
  - VT Monitor zone
- Able to program specific therapies for different arrhythmias.

Therapy Options

- DEFIBRILLATION
- ANTI-TACHYCARDIA PACING
  ~ aka "Painless Therapy"
  ~ Rapid Pacing in short bursts to break VT
- CARDIOVERSION

Source: Medtronic Academy

Exercise Considerations

Know the ICD Settings

*VF detection, VT detection, Therapy Threshold

Maintain Target Heart Rate @ least 10 beats BELOW arrhythmia detection

If the exercise HR is flirting with detection zones, CONTACT THE PATIENT'S PHYSICIAN

*The patient is at risk of getting shocked w/exercise

*Medication titration or ICD reprogramming is warranted

Sample Medtronic Interrogation Report

Medtronic — **Quick Look II**

Device: Evera MRI™ XT DR DDMB1D4 [redacted] Date of Interrogation: 17-Aug-2023 13:25:07

[redacted] ID: MW1786 Physician: [redacted]

History: Primary Prevention, AT/AF + Sinus Node Dysfunction, Normal AV Conduction

Device Status (Implanted: [redacted])

Remaining Longevity 8.7 years (17-Aug-2023)

RRT > 6 years

(based on initial interrogation)

	Atrial(5076)	RV(6935M)
Pacing Impedance	456 ohms	418 ohms
Defibrillation Impedance		RV=61 ohms
Capture Threshold	0.625 V @ 0.40 ms	0.625 V @ 0.40 ms
Measured On	17-Aug-2023	17-Aug-2023
Programmed Amplitude/Pulse Width	1.50 V / 0.40 ms	1.50 V / 0.40 ms
Measured P/ R Wave	4.0 mV	>20 mV
Programmed Sensitivity	0.30 mV	0.30 mV

Parameter Summary

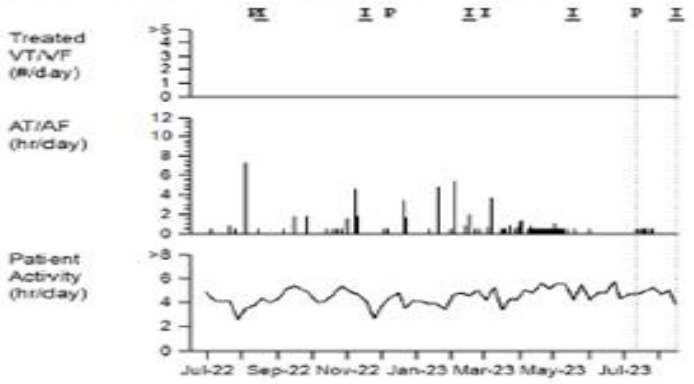
Mode	AAIR<=>DDDR	Lower Rate	60 bpm	Paced AV	180 ms
Mode Switch	171 bpm	Upper Track	140 bpm	Sensed AV	150 ms
		Upper Sensor	140 bpm		

Detection		Rates	Therapies
AT/AF	On (1 zone)	>171 bpm	Burst+, Ramp, CV Off
VF	On	>200 bpm	ATP During Charging, 35J x 6
FVT	OFF		All Rx Off
VT	OFF		All Rx Off

Enhancements On: VT Monitor, AF/Afl, Sinus Tach, Wavelet, Onset(Monitor), TWave, Noise(Timeout)

Clinical Status	Since 12-Jul-2023
Treated	
VF	0
FVT (Off)	
VT (Off)	
AT/AF	0
Monitored	
VT (150-200 bpm)	0
VT-NS (>4 beats, >200 bpm)	0
High Rate-NS	0
SVT: VT/VF Rx Withheld	0
V. Oversensing-TWave Rx Withheld	0
V. Oversensing-Noise Rx Withheld	0
AT/AF	0
Time in AT/AF	<0.1 hr/day (<0.1%)
Functional	**Last Week**
Patient Activity	3.9 hr/day

Cardiac Compass Trends (Jun-2022 to Aug-2023)

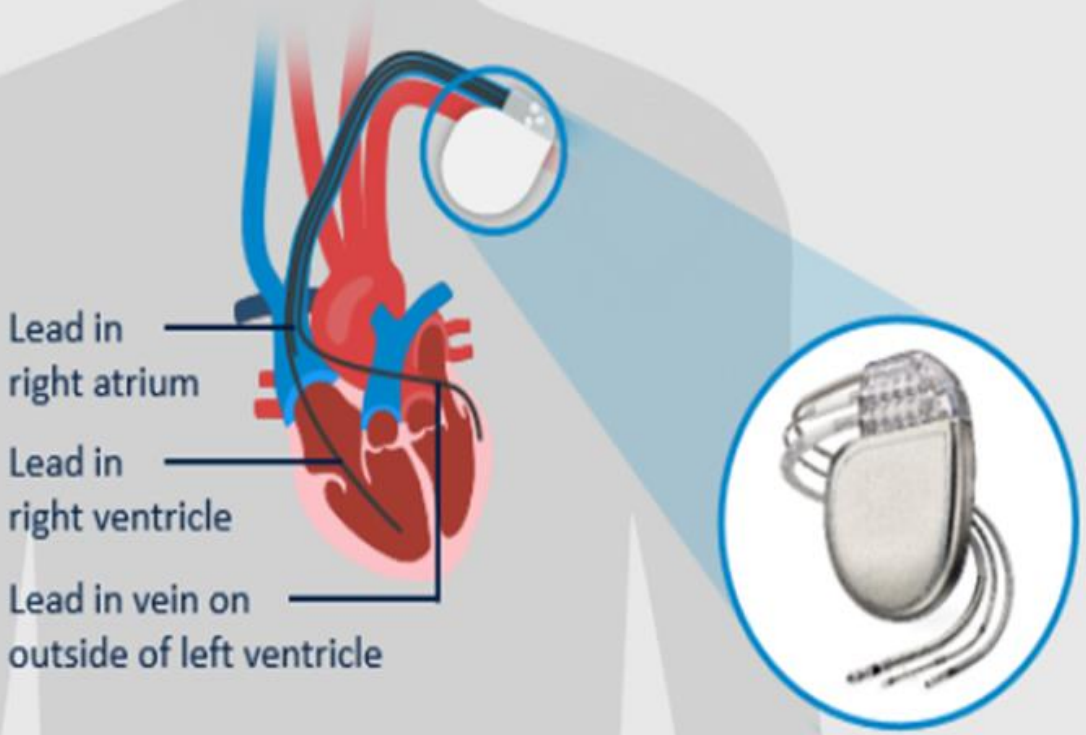


Therapy Summary	VT/VF	AT/AF	Pacing	(% of Time Since 12-Jul-2023)
Pace-Terminated Episodes	0	0	Total VP	1.3% (MVP On)
Shock-Terminated Episodes	0	0	AS-VS	55.6%
Total Shocks	0	0	AS-VP	0.2%

CARDIAC RESYNCHRONIZATION THERAPY (CRT)

CRT devices are implantable devices which pace both ventricles to correct electric desynchrony and improve pumping efficiency. There are two types of CRT:

- CRT-P (pacemaker)
- CRT-D (defibrillator)



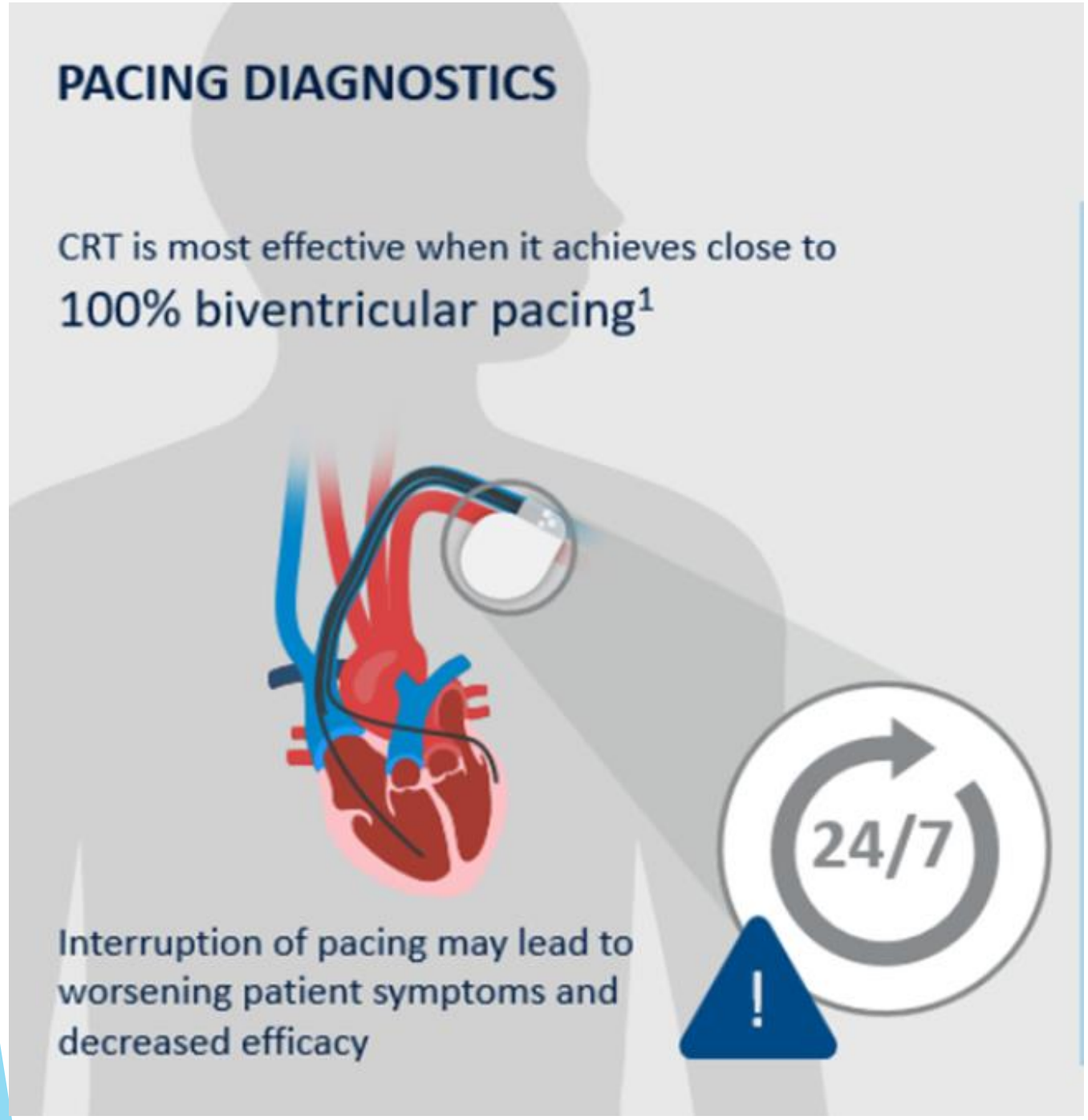
Reduces risk of death and hospitalization[1-12]

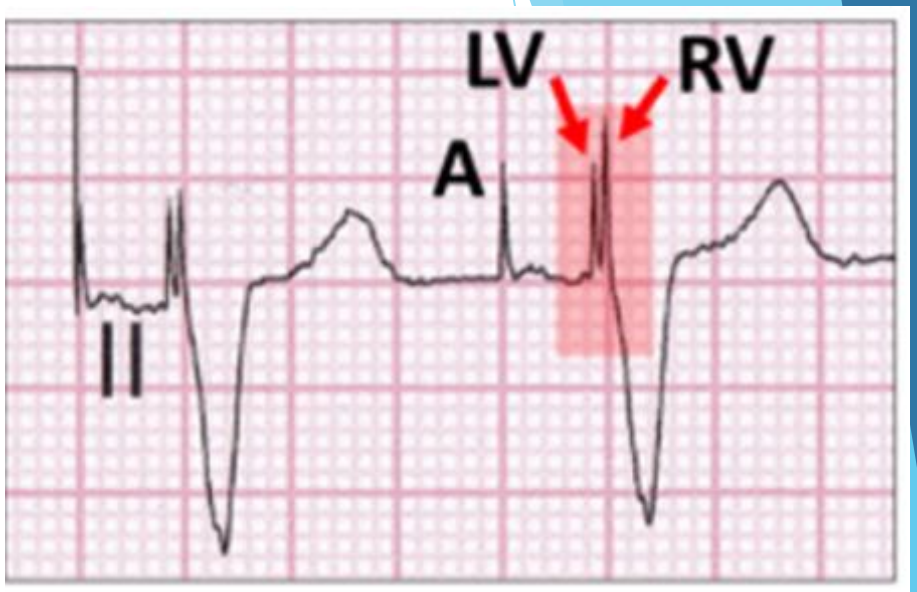
Improves left ventricular systolic function[1-12]

May improve patient symptoms[1-12]

CRT-D and CRT-P patients may experience surgical complications and/or may not receive the benefit of device therapy as expected. With a device, there are surgical limitations and lifestyle limitations, such as avoiding exposure to magnets, which may impact device performance.

Source: Medtronic Academy





BiV-pacing results in a narrower QRS compared to RV-only pacing

Source: Medtronic Academy

WRAPPING UP…

After Implant	• Arm/Shoulder restrictions • Activity and lifting restrictions • Monitoring for infection
Know the NBG Code	• This will tell you A LOT about how the device will function • Is Rate Response ON?
Request Device Settings	• Lower Rate • Upper Tracking Rate • Upper Sensor Rate • VF and VT detection zones • % Pacing
Bringing It All Together	• Monitor HRs during exercise, knowing device settings • Communicate with the MD any changes to or concerns with rates

- Devices are wicked smart, fast and FUN!
- They will always err on the side of caution
- If you don't know…ASK!

Claire discovers that The Clapper operates on the same frequency as Don's pacemaker.

"Pump vigorously if you feel a palpitation. We're still battling with your insurance company for a better pacemaker."

Thank You!