Hemodynamic Considerations of Implantable Devices

David Hayes, MD

BIOTRONIK excellence for life

1

Contributors to Hemodynamics

2022

- Establishing normal rate response
- Restoring AV synchrony
- Maintaining intrinsic ventricular depolarization when appropriate
- Maintaining BiV stimulation in CRT patients
- AV interval considerations
- V-V interval considerations
- Lead position
- Hardware selected

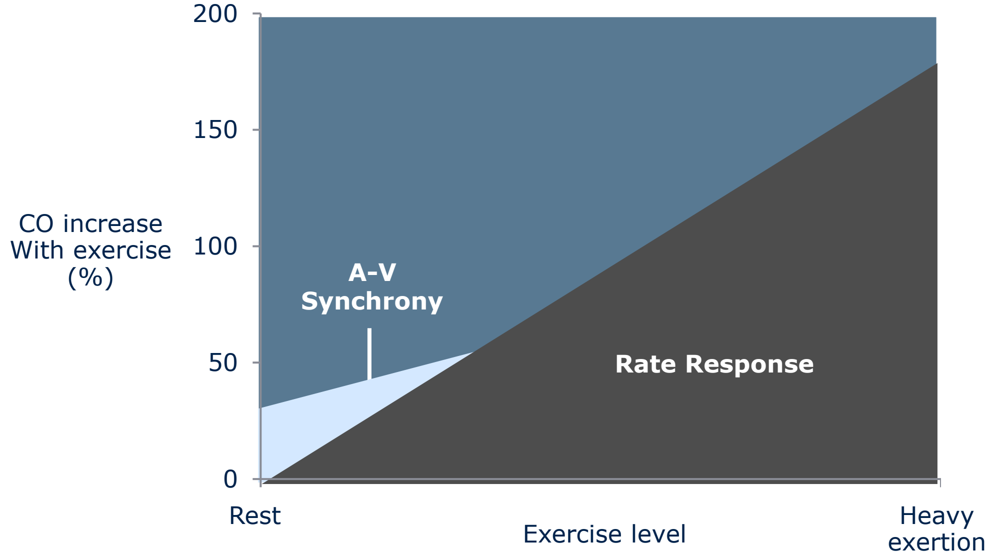
2024

- Establishing or maintaining normal rate response
- Ventricular lead position
- Restoring or maintaining AV synchrony
- Maintaining intrinsic ventricular depolarization when appropriate
- Maintaining BiV stimulation in CRT patients
  - AV interval considerations
  - V-V interval considerations
- Hardware selected

BIOTRONIK excellence for life

2

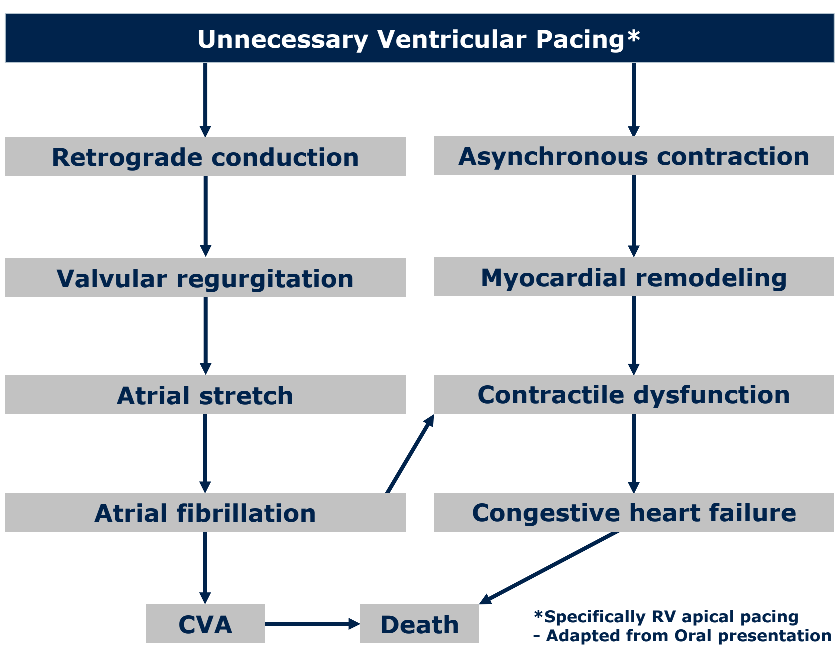
Heart Rate & AV Synchrony: Contribution to Cardiac Output (CO)



Physiologic cardiac pacing: Impact of on-line sensor technology. Can J Card 1988 Jan-Feb;4(1):1-4. Benditt D, et al.

BIOTRONIK
excellence for life

3

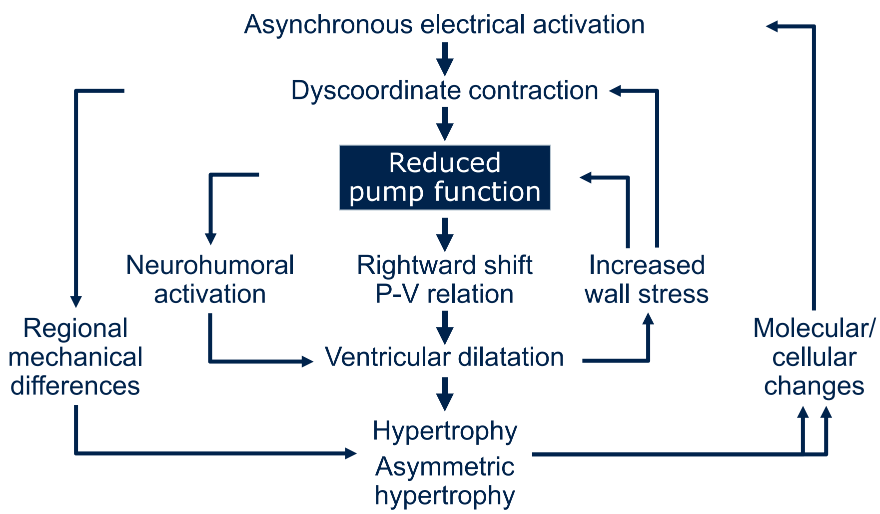


***Specifically RV apical pacing**
- Adapted from Oral presentation A. Gillis – HRS - 1995

BIOTRONIK
excellence for life

4

Mechanisms of Ventricular Remodeling and Progressive Reduction in Pump Function During RV Apical Pacing



Sweeney and Prinzen: JACC 47:282, 2006

5

Pacemaker Syndrome

1. Is largely of historical interest
2. Is unique to ventricular pacing modes
3. Is minimized by ventricular pacing avoidance algorithms
4. Is a result of loss of AV synchrony

6

Pacemaker Syndrome

- An assortment of symptoms related to the adverse hemodynamic impact of the loss of AV synchrony
- Most common with VVI or VVIR
- May occur with ANY PACING MODE if AV synchrony is lost

Potential symptoms

- Malaise/weakness
- Symptomatic Cannon A waves
- Chest pain
- Cough
- Confusion
- Syncope

BIOTRONIK
excellence for life

7

Pacemaker syndrome could be caused by ALL BUT WHICH one of the following?

1. Loss of atrial capture
2. Algorithm to promote intrinsic AV conduction
3. Persistent crosstalk in DDD PM dependent patient in absence of safety pacing
4. Noise sensing on atrial lead in DDD PM
5. Sinus arrest in VDD pacing mode

BIOTRONIK
excellence for life

8

Pacemaker syndrome could be caused by all but which of the following?

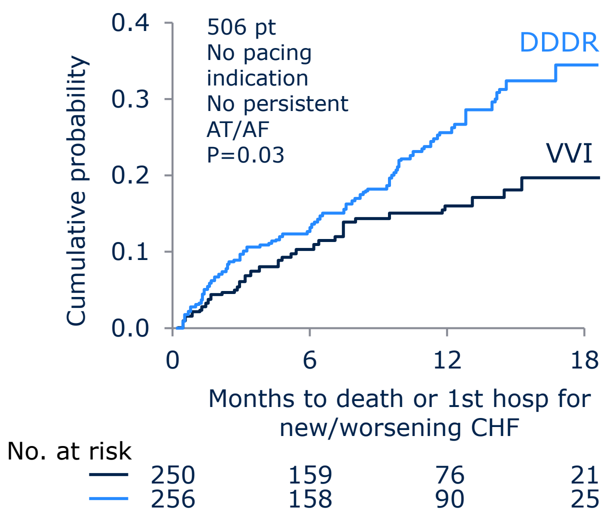
1. Loss of atrial capture – *Results in effective V pacing only*
2. Algorithm to promote intrinsic AV conduction – *In an effort to avoid V pacing the alogrithms may result in AV dissociation*
3. Persistent crosstalk in DDD PM dependent patient in absence of safety pacing – *Would result in ventricular asystole/death and not PM syndrome*
4. Noise sensing on atrial lead in DDD PM – *Responding to noise and not atrial contraction would result in V pacing*
5. Sinus arrest in VDD pacing mode – *Results in V pacing*

BIOTRONIK
excellence for life

9

Relative Risk Relationships
DAVID Trial: Death or Hospitalization

- DDDR mode vs VVI mode and composite endpoint of death or new/worsening heart failure hospitalization
- In DDDR group, pt who survived to 3-mo F-U had worse 12-mo event-free rates when % of RV-pacing was >40% (P=0.09)



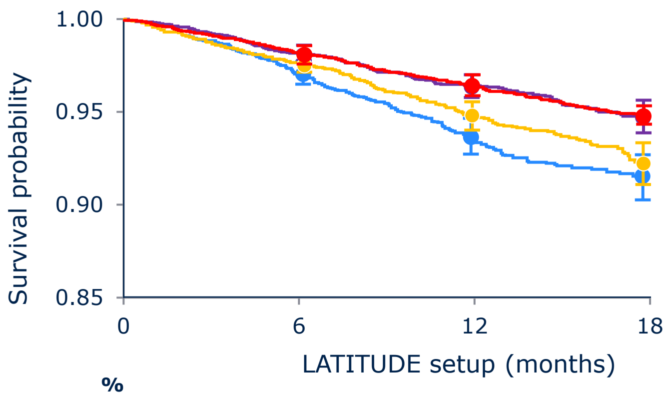
Wilkoff, et al: JAMA 2002; 288; 3115

BIOTRONIK
excellence for life

10

Ventricular Pacing and Survival (%)

Propensity Score/Matched Sample



%				
0	9,829	8,058	5,800	2,099
1-4	3,750	3,015	2,193	850
5-34	3,384	2,739	1,945	647
35-100	2,695	2,143	1,517	520

RV pacing group (vs. 0% pacing)	HR	P
1-4%	1.061	0.530
5-34%	1.449	<0.001
35-100%	1.450	<0.001
Male vs. female	1.004	0.960
Age/5-yr increase	1.290	<0.001

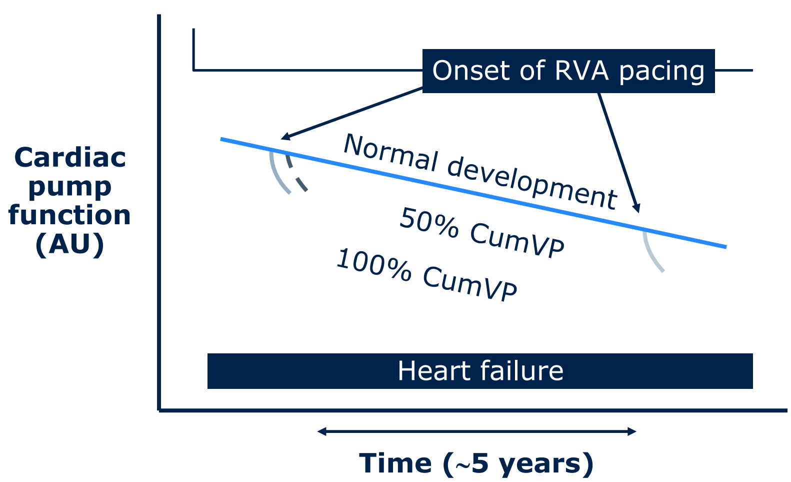
RV pacing group (5-100% vs. 0-4%)	
HR	P
1.426	<0.001

Hayes, et al: HRS Abstract 2009

BIOTRONIK
excellence for life

11

Relationship Between Duration of Mechanical Asynchrony and CHF – Derived from Various Randomized Clinical Trials



Sweeney and Prinzen: JACC 47:282, 2006

BIOTRONIK
excellence for life

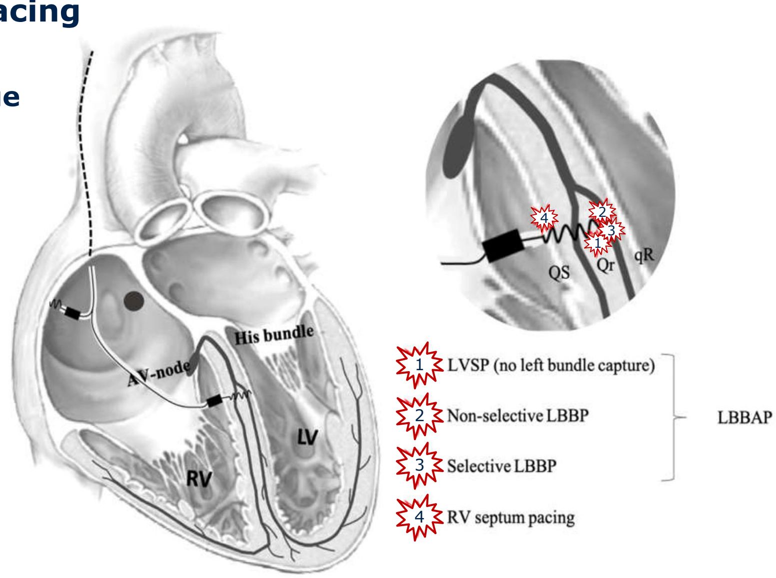
12

Conduction System Pacing: Left Bundle Branch Area Pacing

Capture of the conduction tissue at left side of septum

Associated with:

- Narrow QRS
- Low pacing thresholds
- High sensing values
- Ability to overcome Left bundle branch block

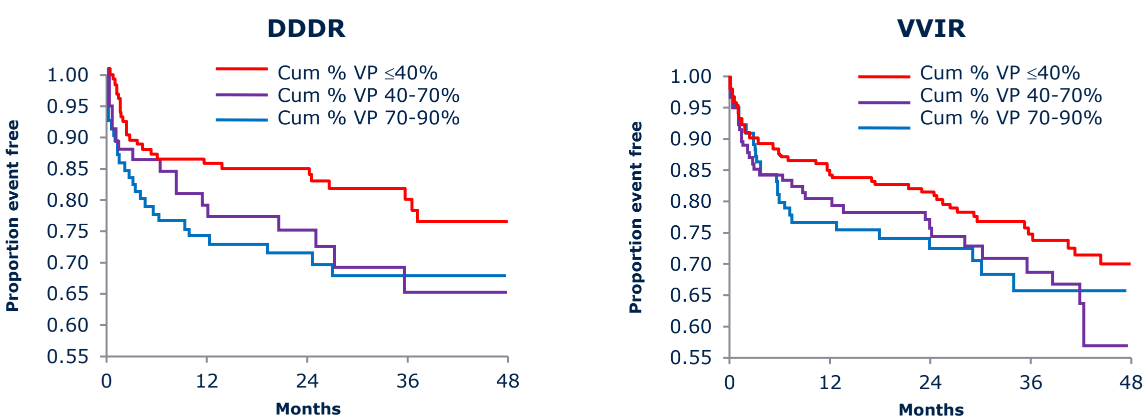


Huang et al, Canadian journal of Cardiology, 2017
Huang er al, Heart Rhythm 2019
Vijayaraman et al, Heart Rhythm 2019
Dr. Jan DePooter, Lead the Pace LBBAP training video, 2021

13

Sinus Node Dysfunction - RV Pacing and AF

AF Risk & Cumulative % Ventricular Pacing

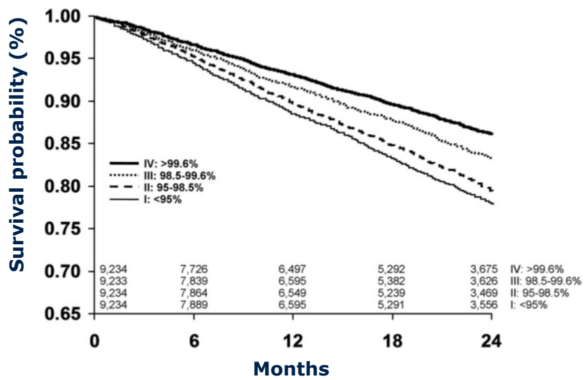


For each 10% ↑ cumulative % VP → ~10% ↑ risk of AF

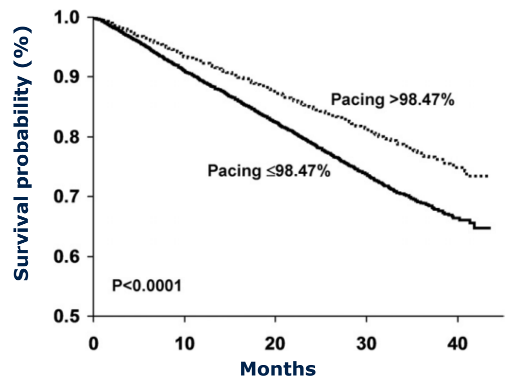
Sweeney et al: Circulation, 2003
MOST = DDDR vs VVIR pacing in SND

14

CRT-D SurvivalQ by BiV Pacing Quartiles (Time from First LATITUDE Interrogation)



CRT-D Survival by BiV Pacing at Optimal Cut-Point



%					
100	11,761	9,524	6,664	2,993	1,075
99	3,943	3,231	2,289	1,031	370
95-98	7,472	6,165	4,382	1,993	722
0-94	7,177	5,724	3,899	1,753	604

15,704	12,755	8,953	4,024	1,445
14,649	11,889	8,281	3,746	1,326

Hayes, et al. HRJ; 8:1469, 2011

BIOTRONIK
excellence for life

15

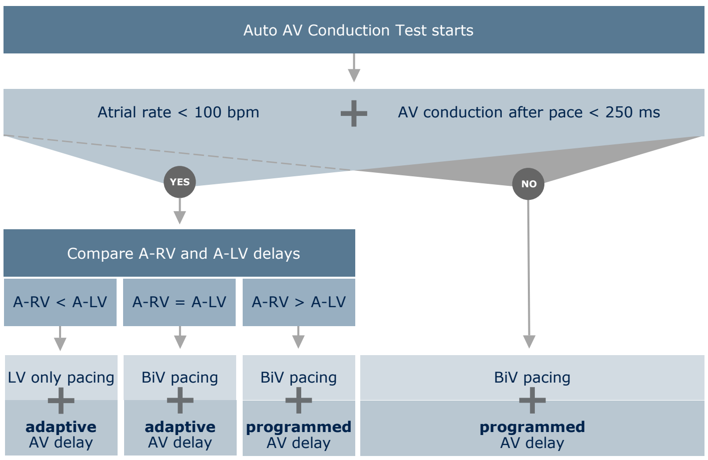
Promoting CRT

- **CRT AutoAdapt:** Designed for continuous CRT optimization. Continuously and dynamically adapts the ventricular pacing configuration and AV delays based on periodic assessment of electrical intracardiac conduction times.
- **MultiPole Pacing:** Allows two programmable LV pacing vectors for each cardiac cycle; 20 LV pacing vectors available in BIOTRONIK current CRT-D systems
- **Trigger Pacing:** Promotes CRT by delivering a LV paced event after a RVs; ensures LV pacing in the event of an RV sense of right-sided PVC.
- **Rate Stabilization during Mode Switch:** Provides stable ventricular rhythm during a mode switch, which could increase BIV pacing percentages. The device utilizes the four most recent ventricular intervals to generate a ventricular rate average and to provide VP support any time the rate drops below the average rate minus 10 bpm
- **Negative Hysteresis:** Promotes ventricular pacing in the presence of hypertrophic cardiomyopathy or heart failure by shortening the AV delay when a sensed R-wave occurs.

BIOTRONIK
excellence for life

16

CRT AutoAdapt Algorithm Flowchart



How does the algorithm work?

Check two prerequisites for continous adaptation:

atrial rate + AV conduction after pace

If both criteria are fulfilled:
compare A-RV delay to A-LV delay

AND

Set LV pacing mode + delay accordingly

In all other cases:

Use BiV pacing + programmed AV delay

BIOTRONIK
excellence for life

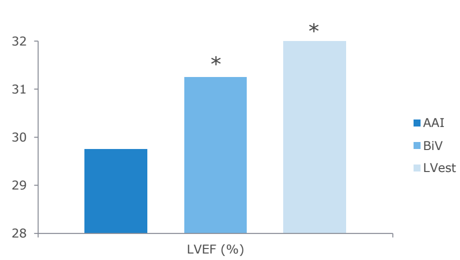
17

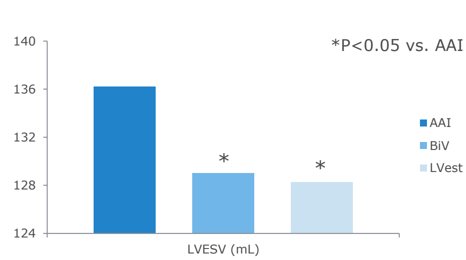
Adapted AV

Adapted AV = shortest of the two values: **70% A-RV** / **A-RV – 40 ms**

Clinical Understanding

- *Khaykin Y et al.* showed the acute hemodynamic effects associated to different ventricular pacing modes and AV and VV delays optimization
- Echocardiography analysis showed that:
  - AV delay close to 70% of the intrinsic A-RVs interval is a reasonable approximation of the optimal value
  - Shortening A-RVs by 40 ms would prevent pacing after the beginning of the intrinsic QRS complex





1 Khaykin Y. EP Europace. 2011, 13 (10).

BIOTRONIK
excellence for life

18

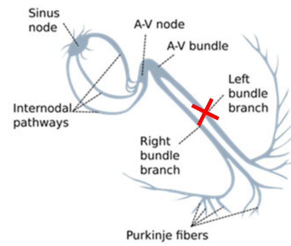
A-RV < A-LV
(at least 20 ms)

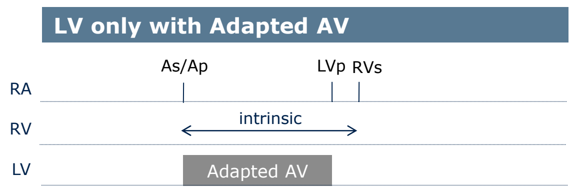
Determine ventricular pacing configuration and optimize AV delay

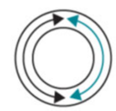
- Ventricular pacing: **LV only**
- AV delay: **Adapted AV**

Adapted AV‡ = shortest of the two values: **70% A-RV** / **A-RV – 40 ms**

‡Khaykin Y et al. *Europace*. 2011;13(10)







Fusion

19

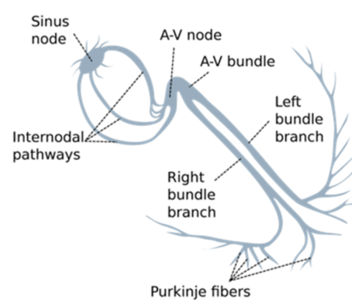
A-RV = A-LV
(± 20 ms)

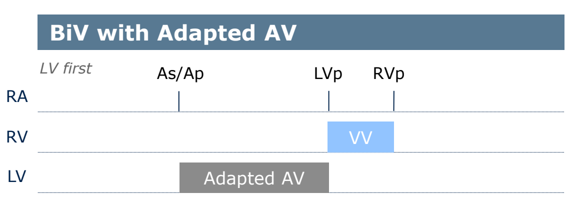
Determine ventricular pacing configuration and optimize AV delay

- Ventricular pacing: **BiV**
- AV delay: **Adapted AV**

Adapted AV‡ = shortest of the two values: **70% AV[1]** / **AV[1] – 40 ms**

‡Khaykin Y et al. *Europace*. 2011;13(10)





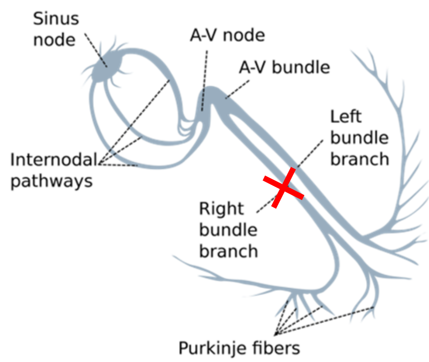
[1] The algorithm takes the shortest interval between A-RV and A-LV

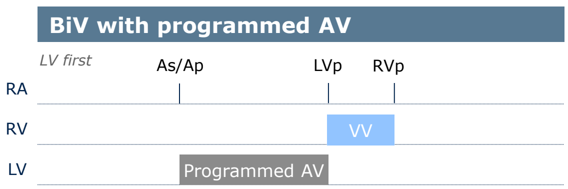
20

A-RV > A-LV
(at least 20 ms)

Determine ventricular pacing configuration and optimize AV delay

- Ventricular pacing: **BiV**
- AV delay: **Programmed AV** *(permanent program)*





BIOTRONIK
excellence for life

21

Hemodynamic Goals of Device Therapy

- Bradycardia-indicated patients (pacemaker and ICD patients)
  - Prevent symptomatic bradycardia
  - Provide rate response when necessary
  - Maintain normal ventricular activation sequence whenever possible
    - Minimal ventricular pacing modes
    - Conduction system pacing
- CRT – maintain biventricular pacing as close to 100% as possible
- ICD patients with no brady indications
  - VT/VF detection
  - Maintain normal ventricular activation sequence whenever possible

BIOTRONIK
excellence for life

22

Optimizing Hemodynamics

66 yo with intermittent CHB; LV ejection fraction = 40%; you believe he will require pacing <40% of the time. Which of the following would provide optimal hemodynamics?

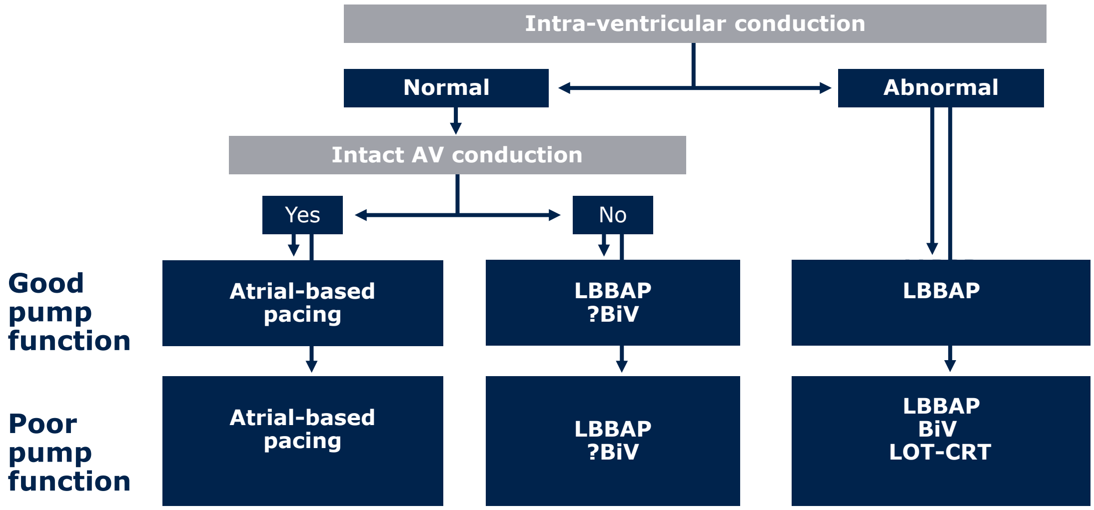
1. DDD with apical V lead
2. DDD with LBBAP
3. CRT-P
4. CRT-D
5. VVI with LBBAP lead positioning

Optimizing Hemodynamics

66 yo with **intermittent CHB**; LV ejection fraction = **40%**; you believe he will require pacing **< 40%** of the time. Which of the following would provide optimal hemodynamics?

1. DDD with apical V lead
2. DDD with LBBAP
3. CRT-P
4. CRT-D
5. VVI with LBBAP lead positioning

Algorithm for Physiological Pacing Consideration



Modified from Sweeney and Prinzen: JACC 47:282, 2006. BIOTRONIK pacing leads are approved for traditional delivery and placement per indications for use and are not FDA approved for Conduction System Pacing (including His Bundle and Left Bundle Area Pacing).

BIOTRONIK excellence for life

25

Hemodynamic Considerations of Implantable Devices

David Hayes, MD

BIOTRONIK excellence for life

26