Keeping the Pace

2023 Heart & Vascular Conference
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Disclosures

I have no financial conflicts of interest to disclose

Objectives

- Define the various forms of Cardiac Physiologic pacing consistent with the recent HRS guideline (2 weeks ago!)
- Understand the benefits of Cardiac Physiologic Pacing
- Know some of the indications for Cardiac Physiologic Pacing
- A brief understanding of the procedure and mechanism of resynchronization
- Understand the follow-up of patients with Cardiac Physiologic Pacing

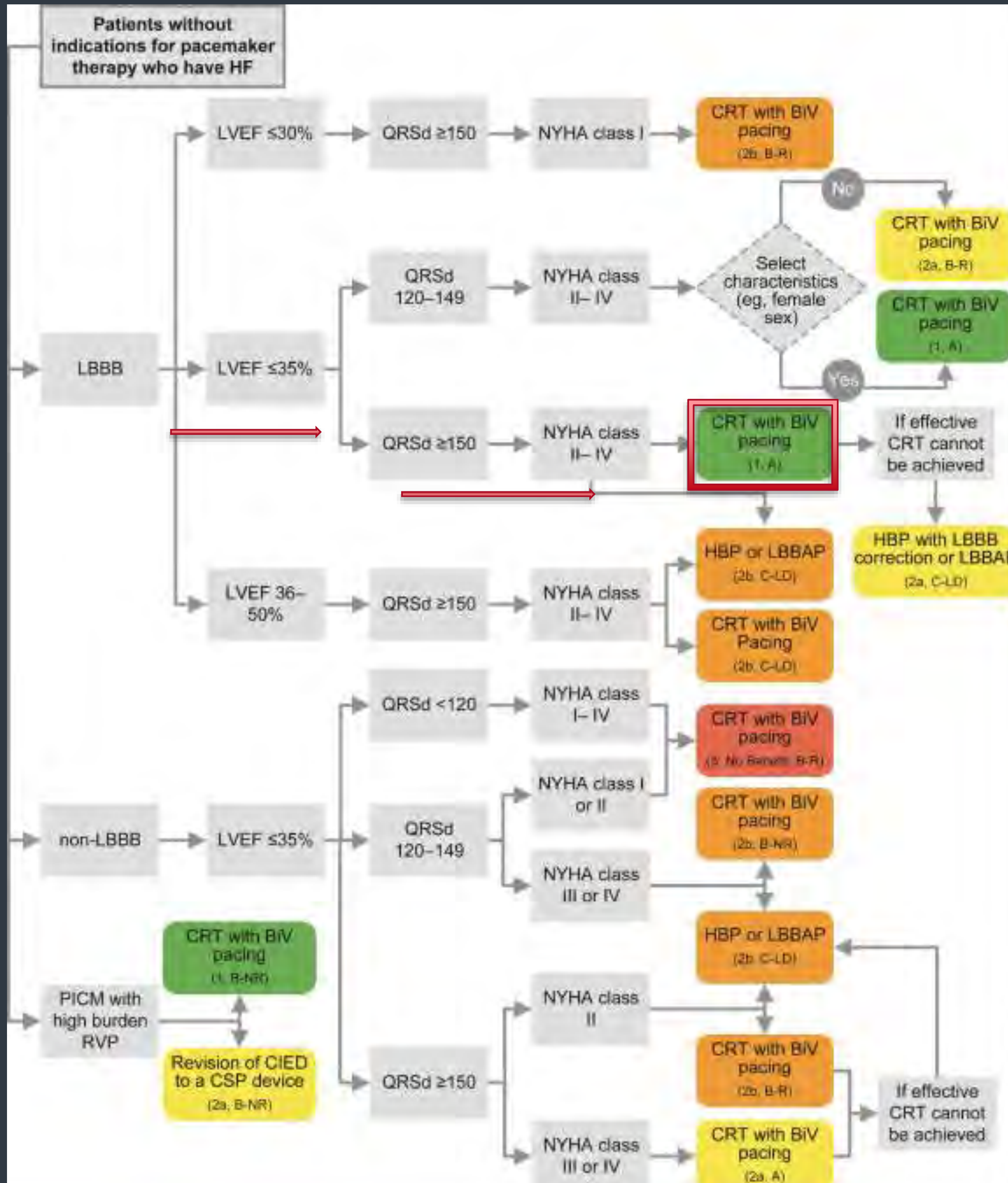
Definitions (New guidelines)

- Cardiac Physiologic Pacing
    - **pacing intended to restore or preserve ventricular synchrony**
- His Bundle Pacing
    - Direct stimulation of the His Bundle to engage conduction system
- Left Bundle Branch Area Pacing
    - Direct pacing of any part of the LBB fascicular system
- Cardiac Resynchronization therapy
    - Aims to restore or preserve ventricular synchrony, most commonly refers to BiV pacing
- Biventricular Pacing
    - Two ventricular leads, on in RVA and one in the coronary sinus

.Chung, M. K. *et al.* 2023 HRS/APHRS/LAHRS guideline on cardiac physiologic pacing for the avoidance and mitigation of heart failure. *Hear. Rhythm* **20**, e17–e91 (2023).

Case

- 30-year-old male
- Dilated Cardiomyopathy Diagnosed in 2015
- LV EF at diagnosis was 10%
- On GDMT, his LV EF improved to 50% by March 2016
- Did well until November of 2021, when he had a decline in EF to 20% and HF exacerbation
- LBBB with QRS duration> 150 ms



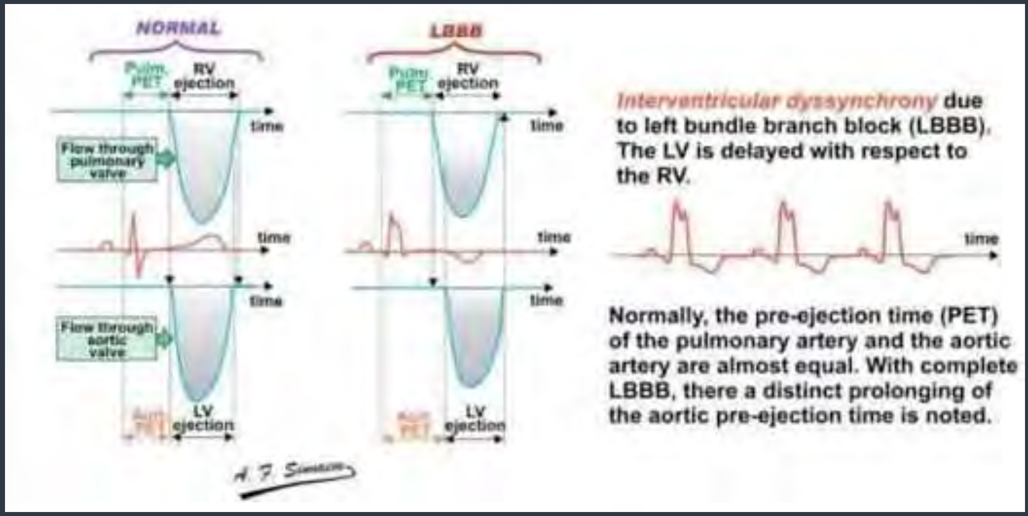
Patients without indications for pacemaker therapy who have HF
LBBB
LVEF ≤30%
QRSd ≥150
NYHA class I
CRT with BiV pacing (2b, B-R)
LVEF ≤35%
QRSd 120–149
NYHA class II– IV
Select characteristics (eg, female sex)
No
CRT with BiV pacing (2a, B-R)
Yes
CRT with BiV pacing (1, A)
QRSd ≥150
NYHA class II– IV
CRT with BiV pacing (1, A)
If effective CRT cannot be achieved
HBP with LBBB correction or LBBAP (2a, C-LD)
LVEF 36–50%
QRSd ≥150
NYHA class II– IV
HBP or LBBAP (2b, C-LD)
CRT with BiV Pacing (2b, C-LD)
non-LBBB
LVEF ≤35%
QRSd <120
NYHA class I– IV
CRT with BiV pacing (3: No Benefit, B-R)
QRSd 120–149
NYHA class I or II
CRT with BiV pacing (2b, B-NR)
NYHA class III or IV
HBP or LBBAP (2b, C-LD)
QRSd ≥150
NYHA class II
CRT with BiV pacing (2b, B-R)
NYHA class III or IV
CRT with BiV pacing (2a, A)
If effective CRT cannot be achieved
PICM with high burden RVP
CRT with BiV pacing (1, B-NR)
Revision of CIED to a CSP device (2a, B-NR)

Benefits of CRT

- In patients with heart failure, low EF <35% and dysynchrony (LBBB), CRT with BiV has become accepted as a treatment modality for these patients.

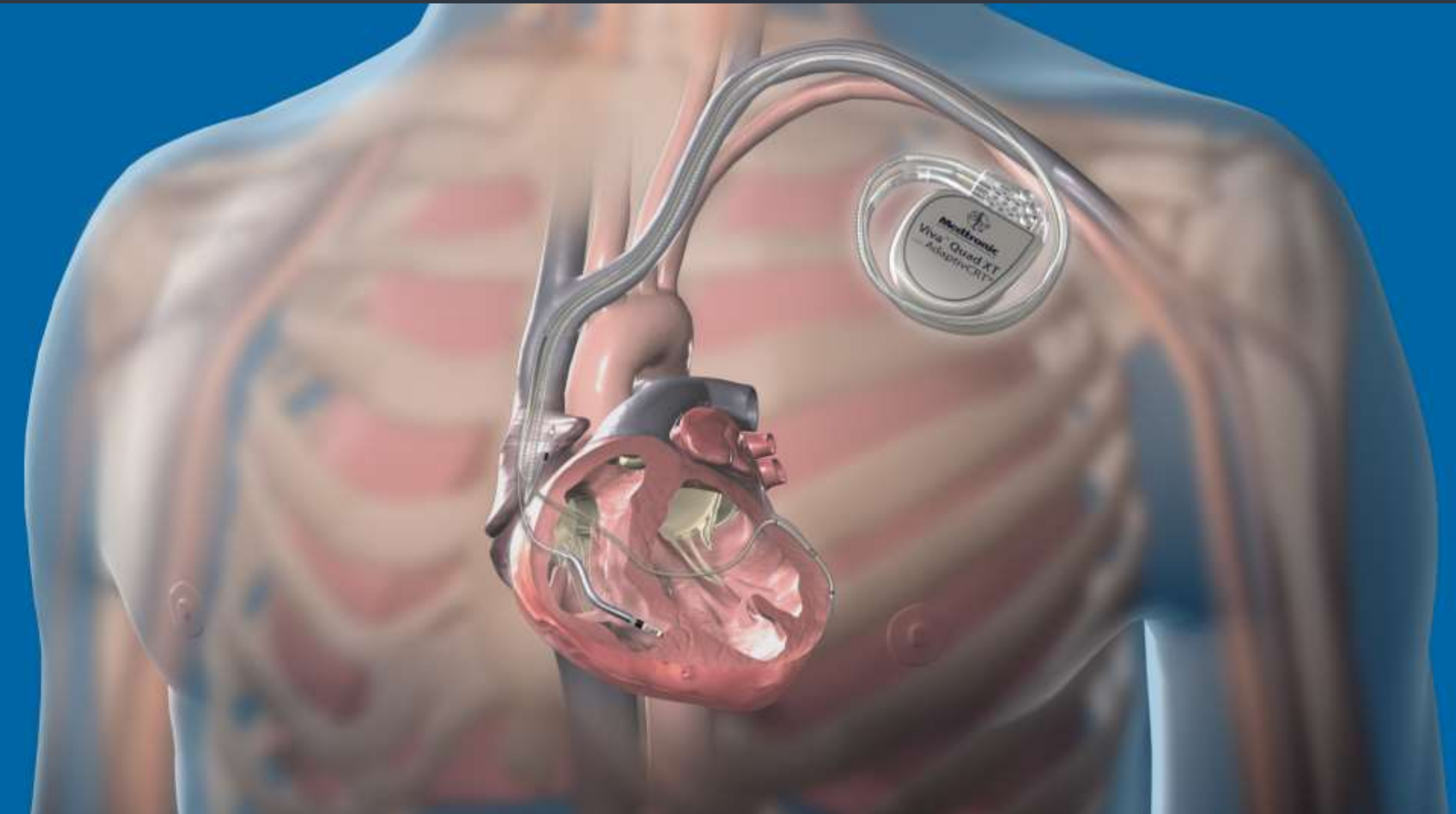
- About 70% of patients who meet these criteria will respond to CRT
  - Improvement in EF
  - Improvement in symptoms
  - Reduction in LV volume

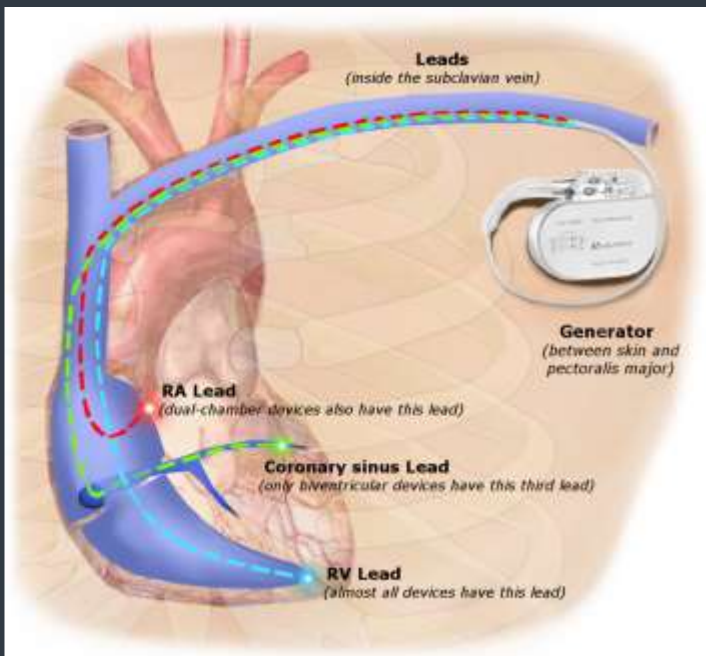
- CRT is also useful in patients with some patients with RBBB
- CTRT is also useful in patient with EF < 50% who require > 20 % ventricular pacing

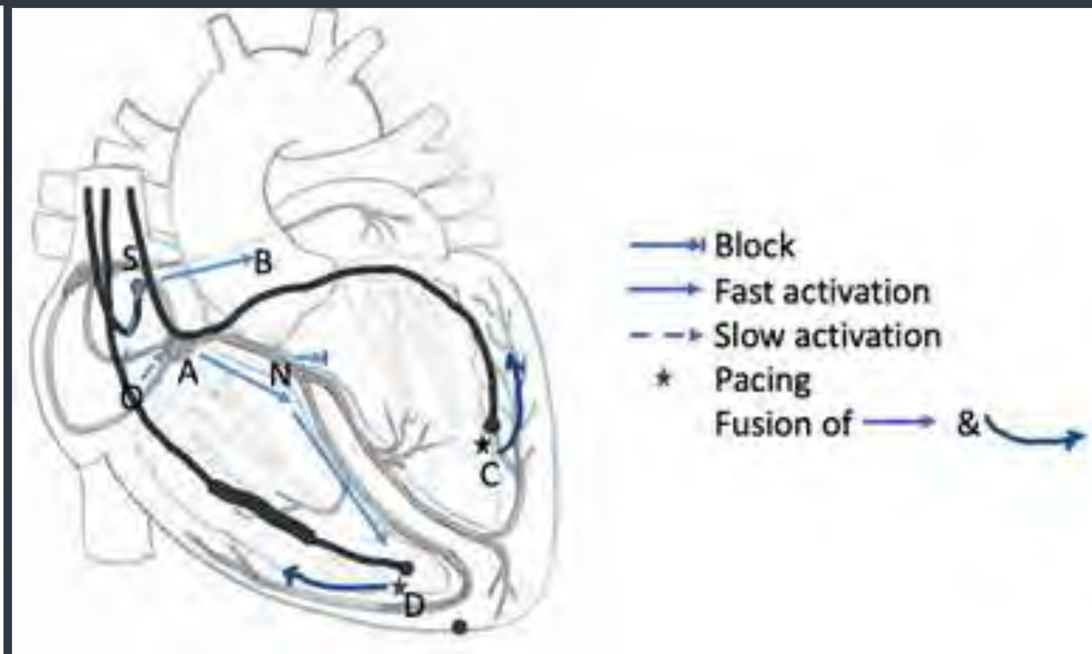


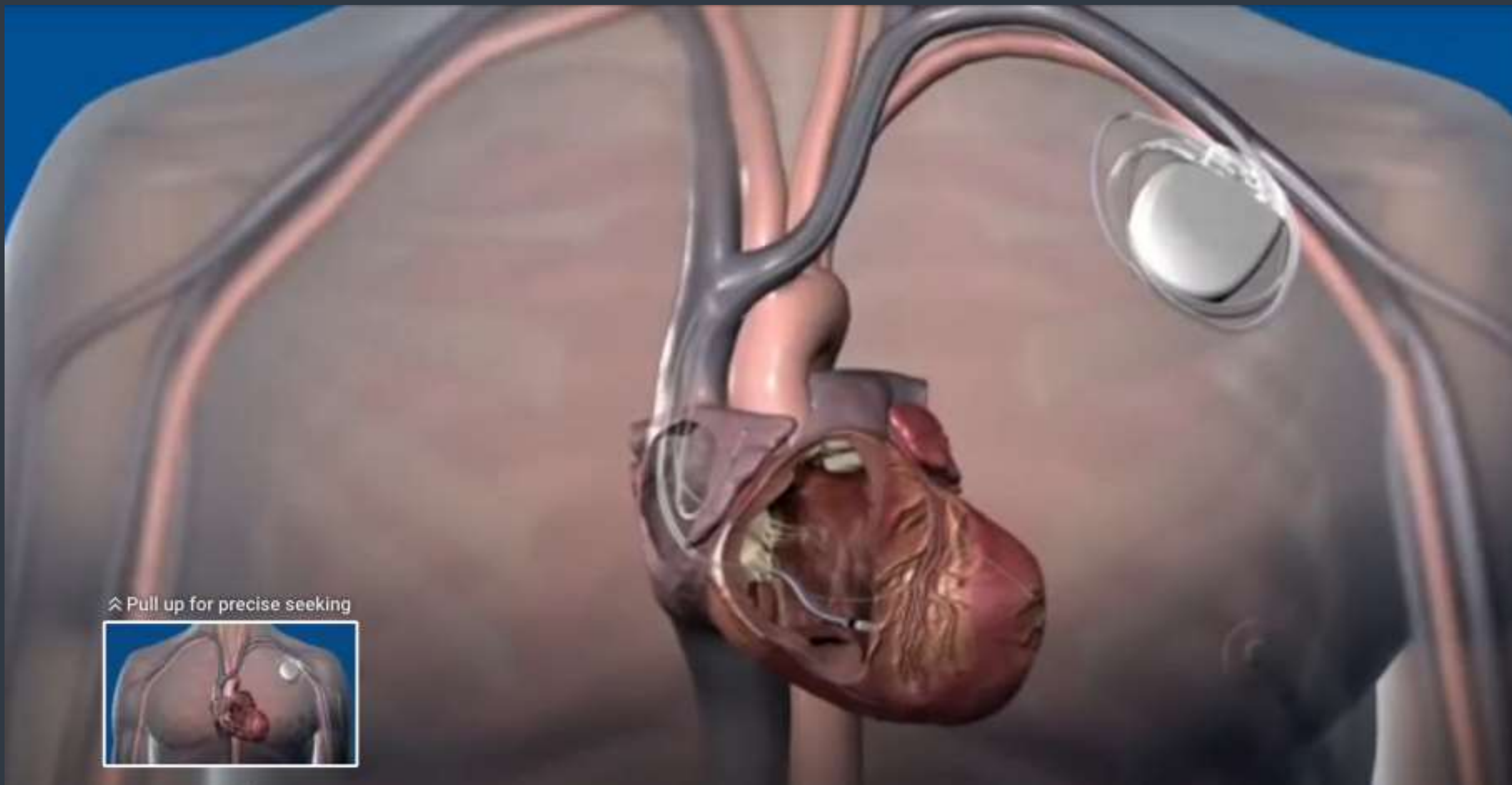
Case

- Underwent Bi-V ICD implant in March 2022 at another facility.

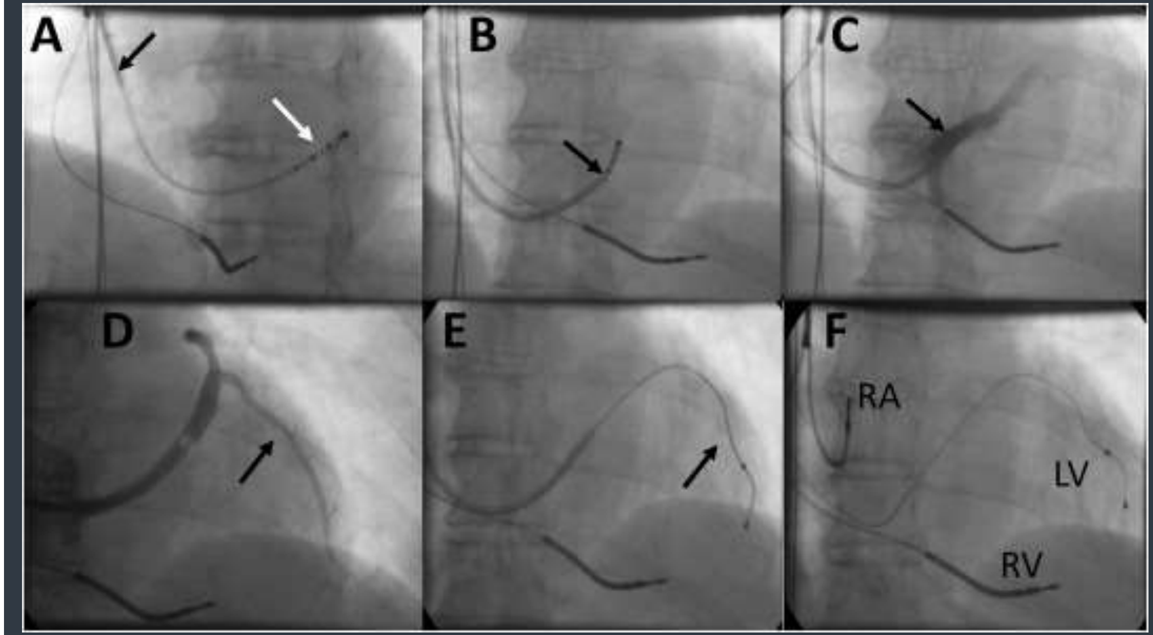

Medtronic
Viva Quad XT

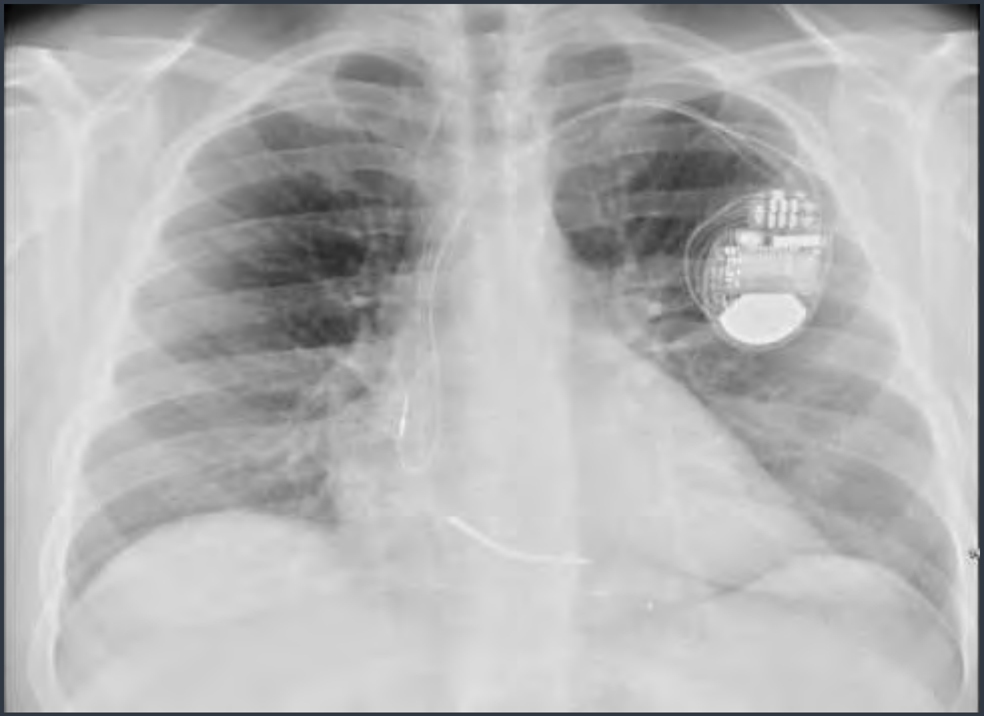

Leads
(inside the subclavian vein)
Generator
(between skin and pectoralis major)
RA Lead
(dual-chamber devices also have this lead)
Coronary sinus Lead
(only biventricular devices have this third lead)
RV Lead
(almost all devices have this lead)

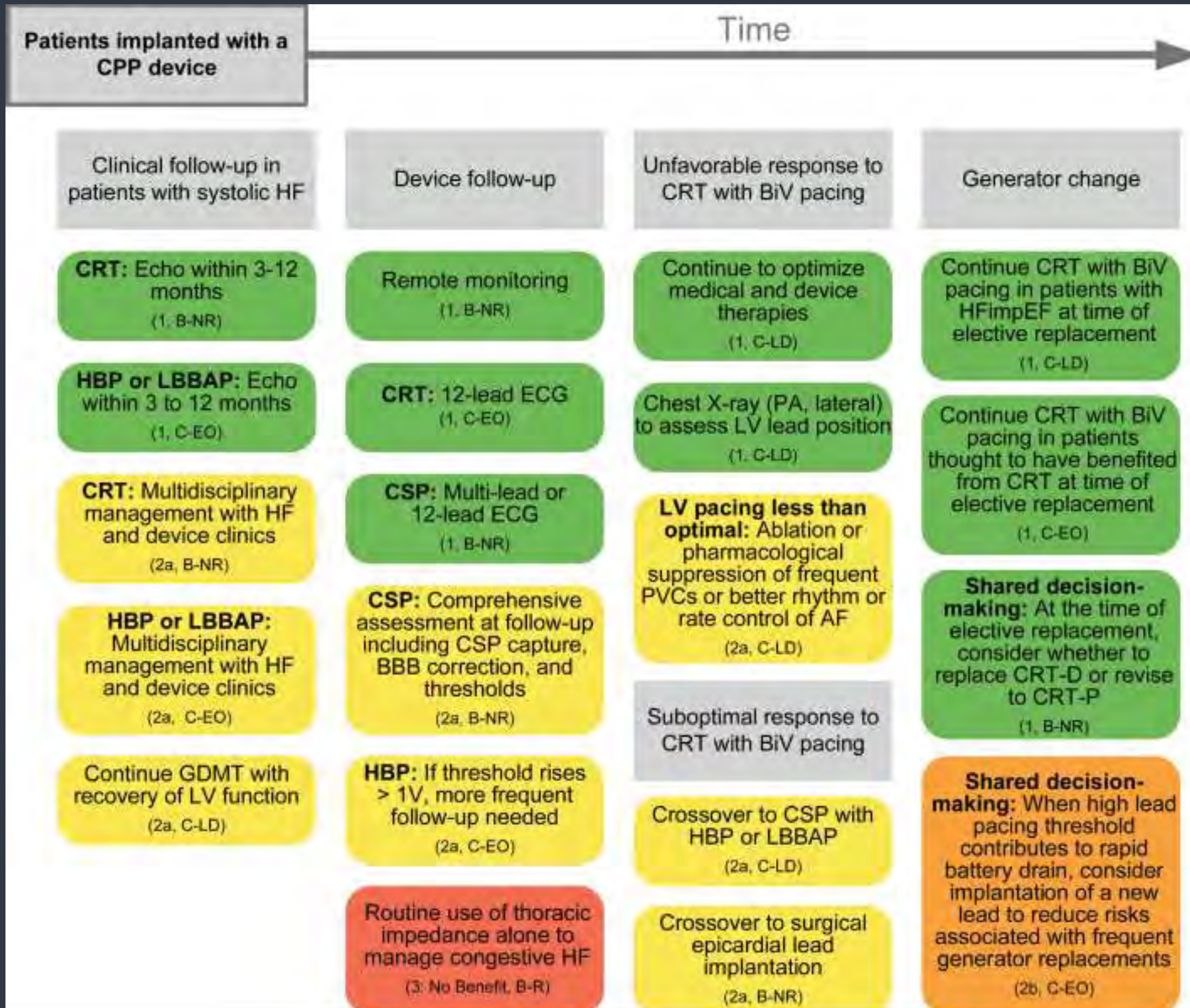

S
B
A
N
O
C
D
Block
Fast activation
Slow activation
Pacing
Fusion of &


Pull up for precise seeking


Braided Core
Depth
Positioning Marker
Integrated Peel-Away
Hemostasis Valve
Side Port
9F Pebax Sheath
Soft Radiopaque Tip
Multiple Introducer Angles


A
B
C
D
E
F
RA
LV
RV



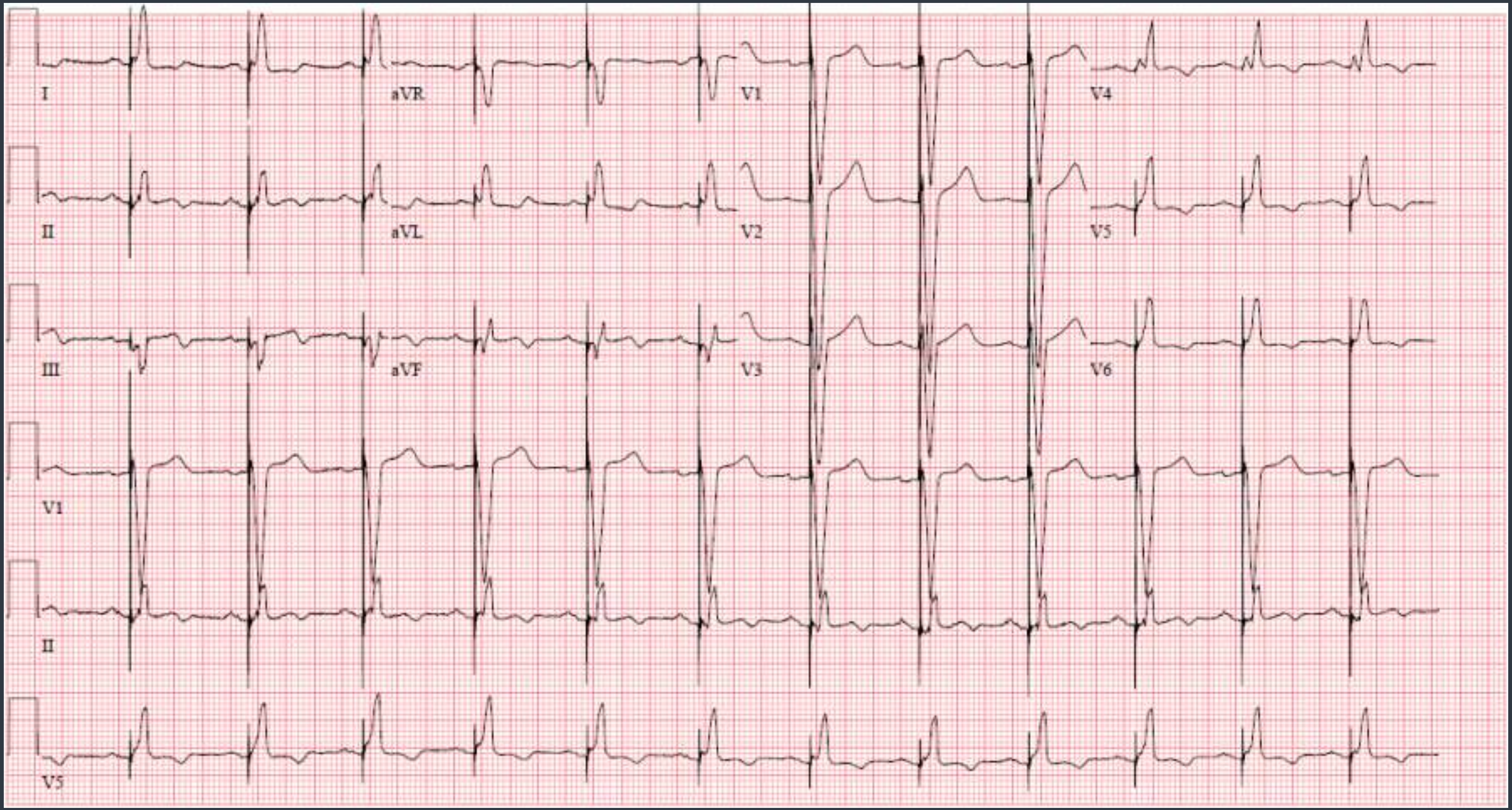


Patients implanted with a CPP device
Time
Clinical follow-up in patients with systolic HF
Device follow-up
Unfavorable response to CRT with BiV pacing
Generator change
CRT: Echo within 3-12 months (1, B-NR)
HBP or LBBAP: Echo within 3 to 12 months (1, C-EO)
CRT: Multidisciplinary management with HF and device clinics (2a, B-NR)
HBP or LBBAP: Multidisciplinary management with HF and device clinics (2a, C-EO)
Continue GDMT with recovery of LV function (2a, C-LD)
Remote monitoring (1, B-NR)
CRT: 12-lead ECG (1, C-EO)
CSP: Multi-lead or 12-lead ECG (1, B-NR)
CSP: Comprehensive assessment at follow-up including CSP capture, BBB correction, and thresholds (2a, B-NR)
HBP: If threshold rises > 1V, more frequent follow-up needed (2a, C-EO)
Routine use of thoracic impedance alone to manage congestive HF (3: No Benefit, B-R)
Continue to optimize medical and device therapies (1, C-LD)
Chest X-ray (PA, lateral) to assess LV lead position (1, C-LD)
LV pacing less than optimal: Ablation or pharmacological suppression of frequent PVCs or better rhythm or rate control of AF (2a, C-LD)
Suboptimal response to CRT with BiV pacing
Crossover to CSP with HBP or LBBAP (2a, C-LD)
Crossover to surgical epicardial lead implantation (2a, B-NR)
Continue CRT with BiV pacing in patients with HFimpEF at time of elective replacement (1, C-LD)
Continue CRT with BiV pacing in patients thought to have benefited from CRT at time of elective replacement (1, C-EO)
Shared decision-making: At the time of elective replacement, consider whether to replace CRT-D or revise to CRT-P (1, B-NR)
Shared decision-making: When high lead pacing threshold contributes to rapid battery drain, consider implantation of a new lead to reduce risks associated with frequent generator replacements (2b, C-EO)

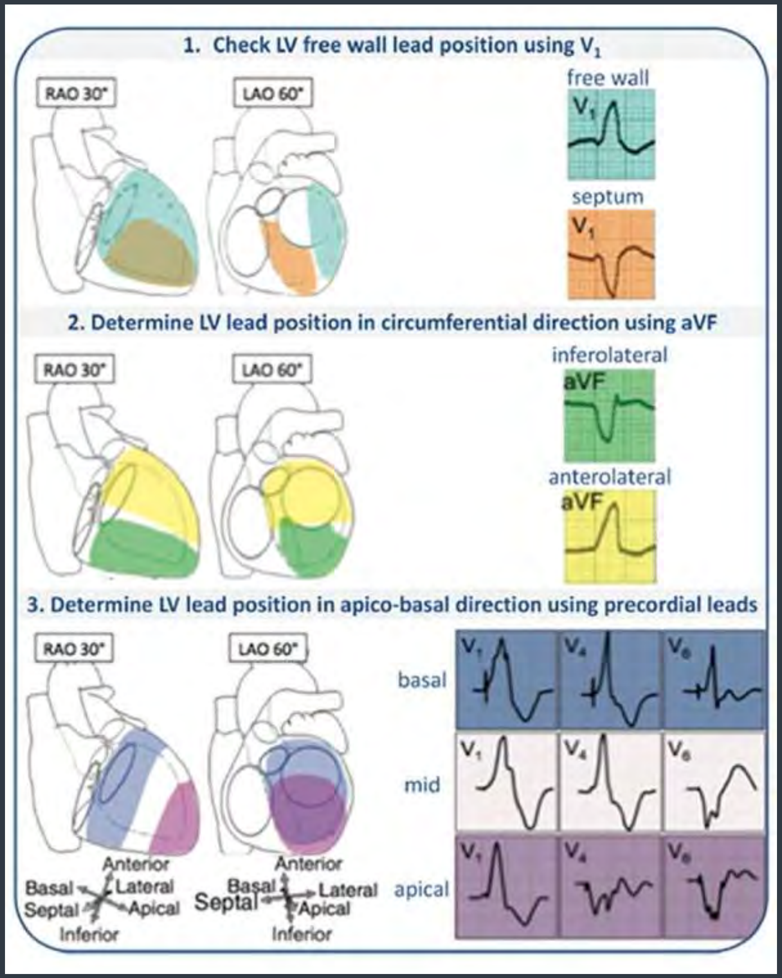
Case

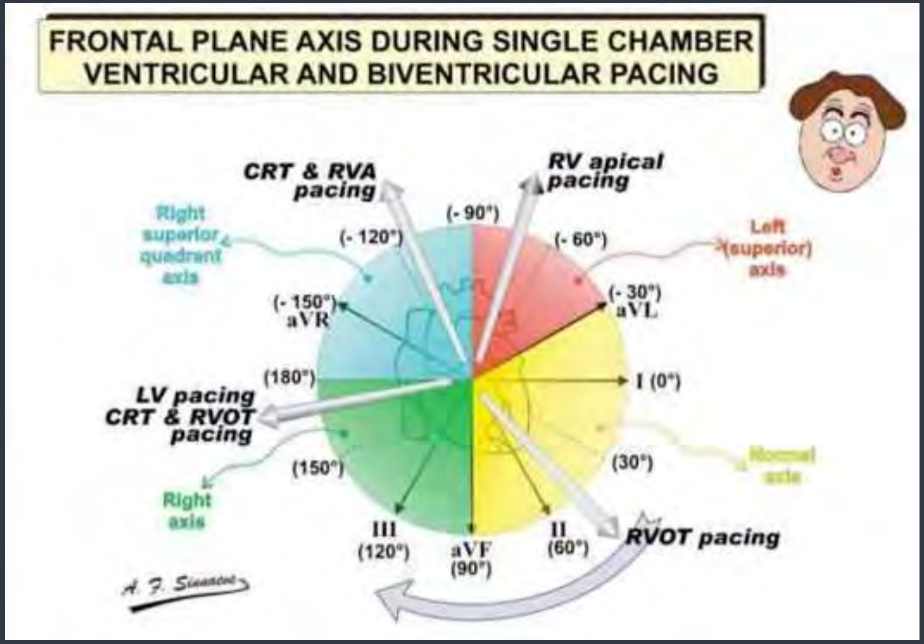
- However, EF remained at 25%
- Stage D, NYHA III-IV
- He was referred to UNMC for a transplant
- HF referred to EP

EP clinic

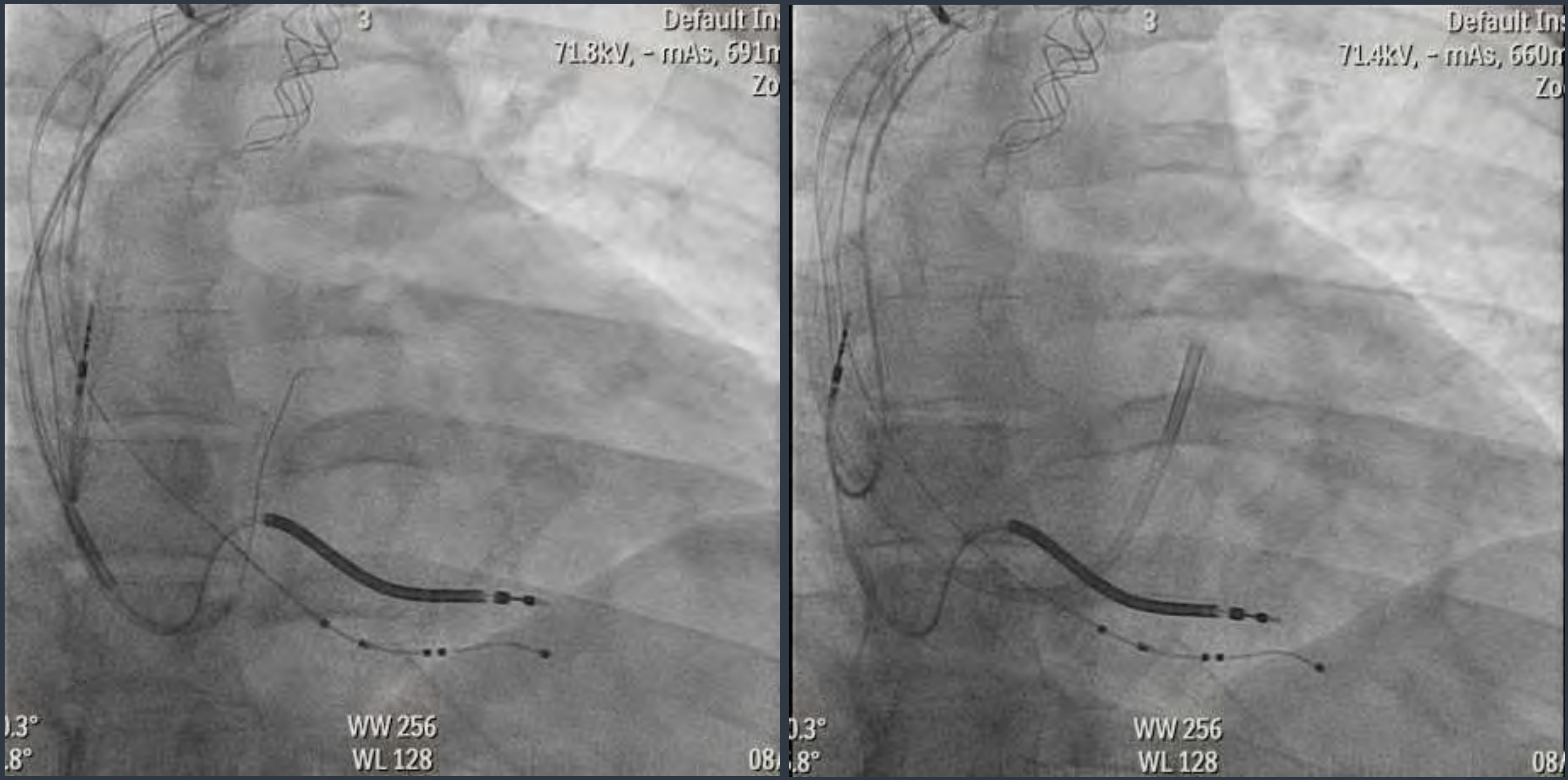


EKG in BiV Pacing

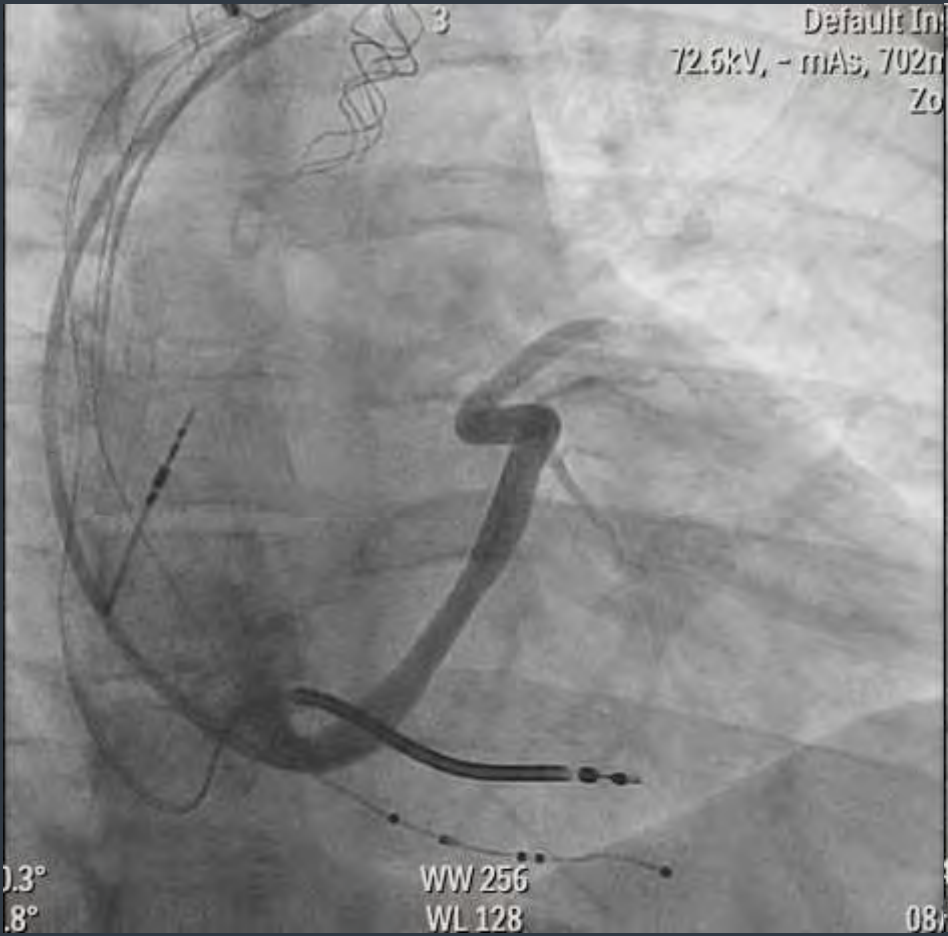


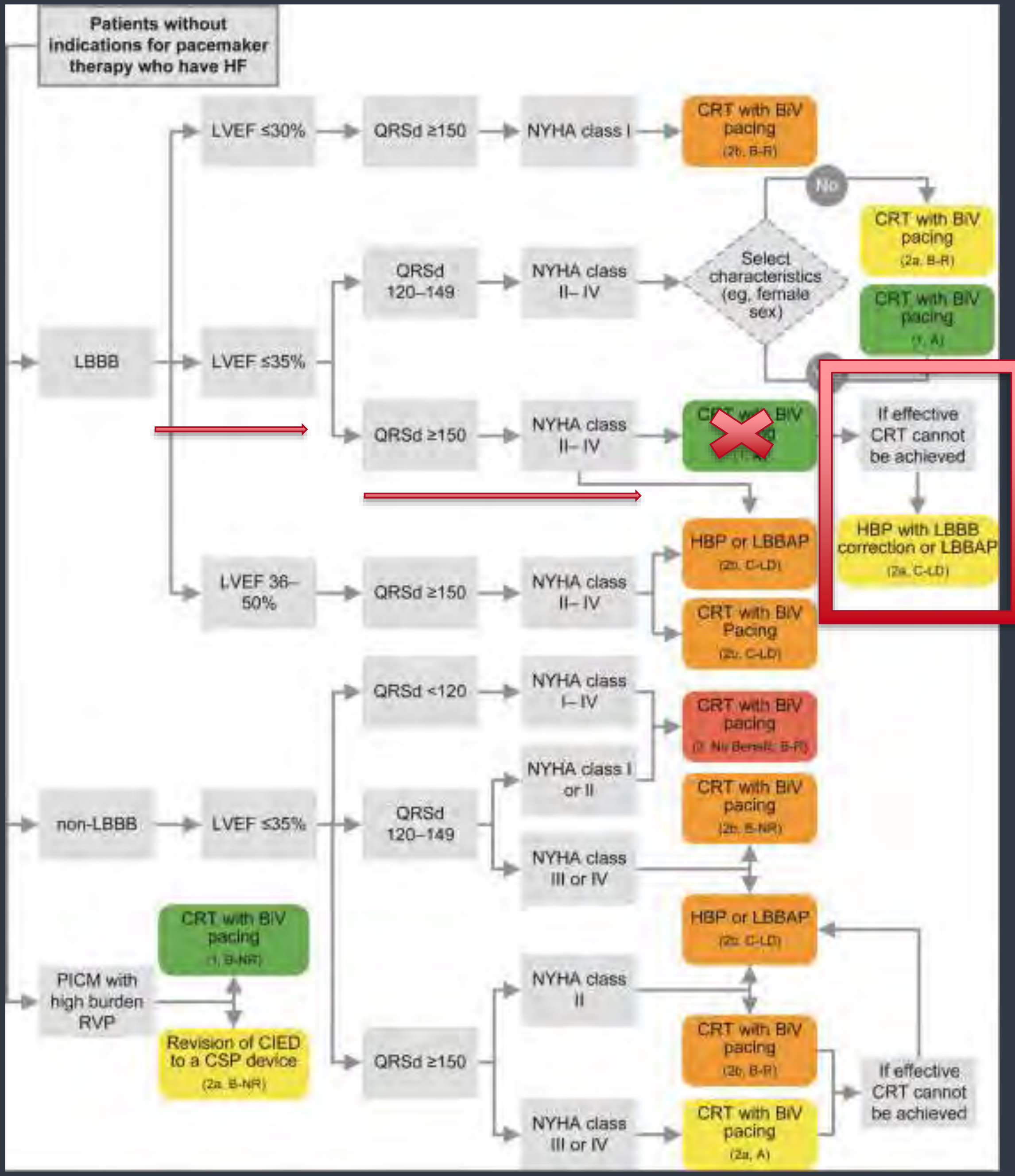


Easy Peasy!


3
Default In
71.8kV, - mAs, 691m
Zo
).3°
.8°
WW 256
WL 128
08
3
Default In
71.4kV, - mAs, 660m
Zo
).3°
.8°
WW 256
WL 128
08

One million years later.....Mood is not Good!

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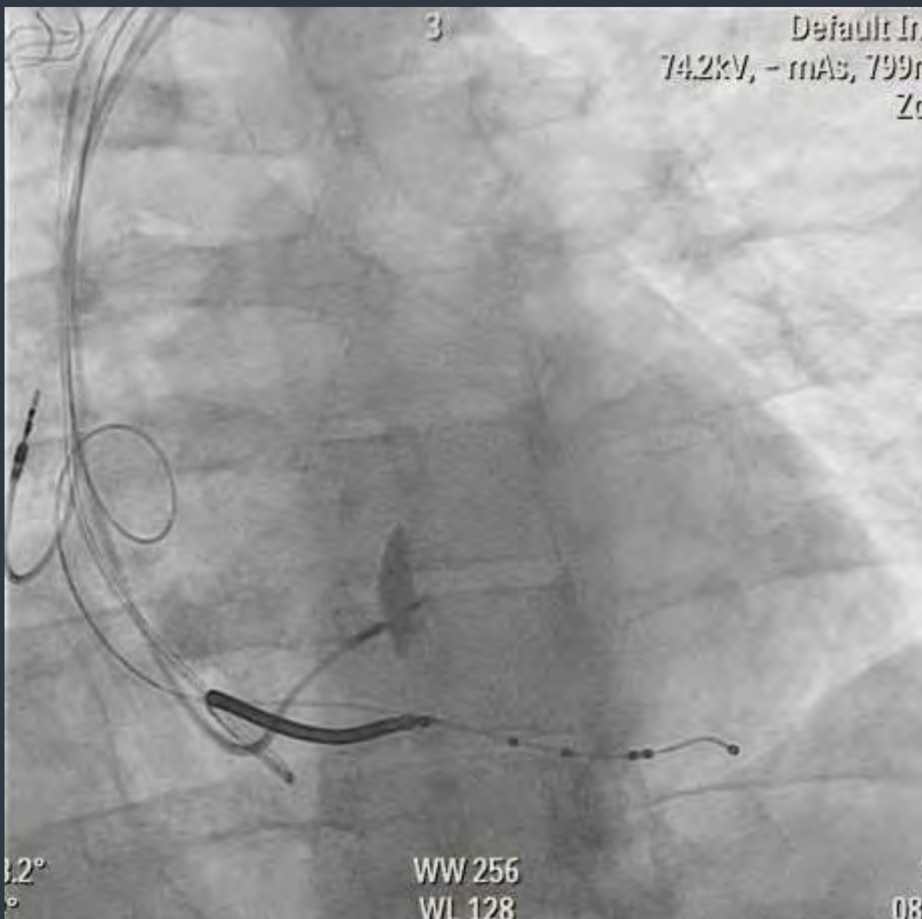
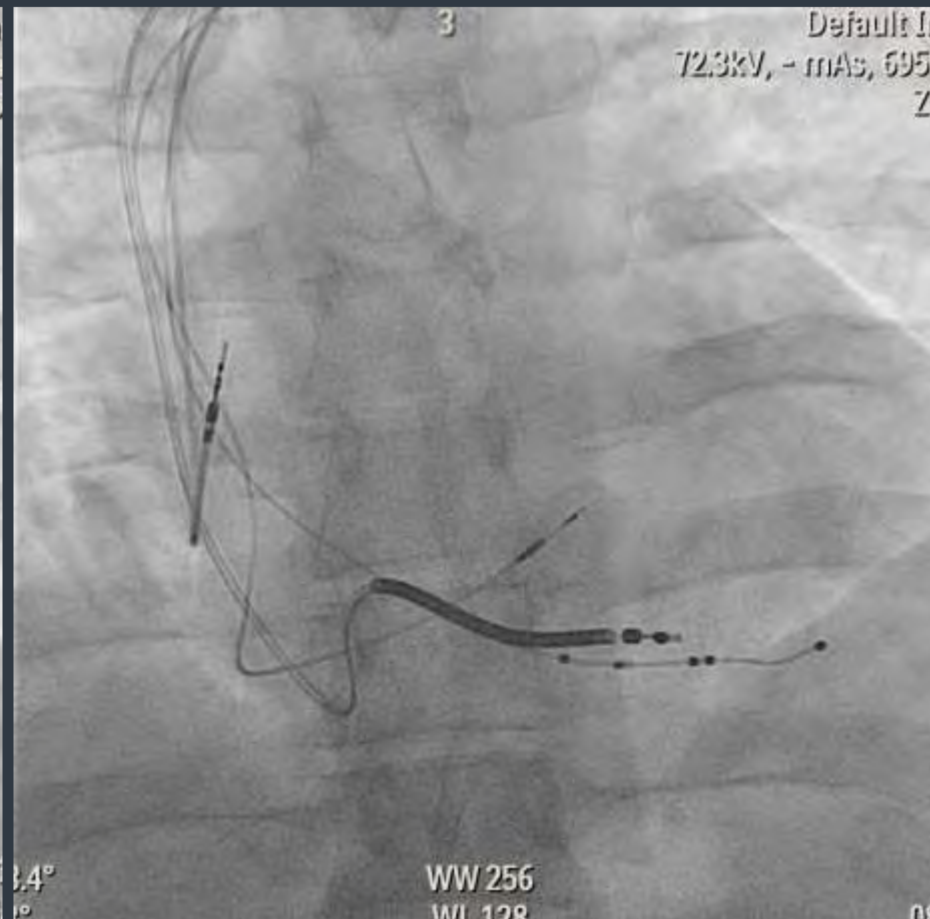
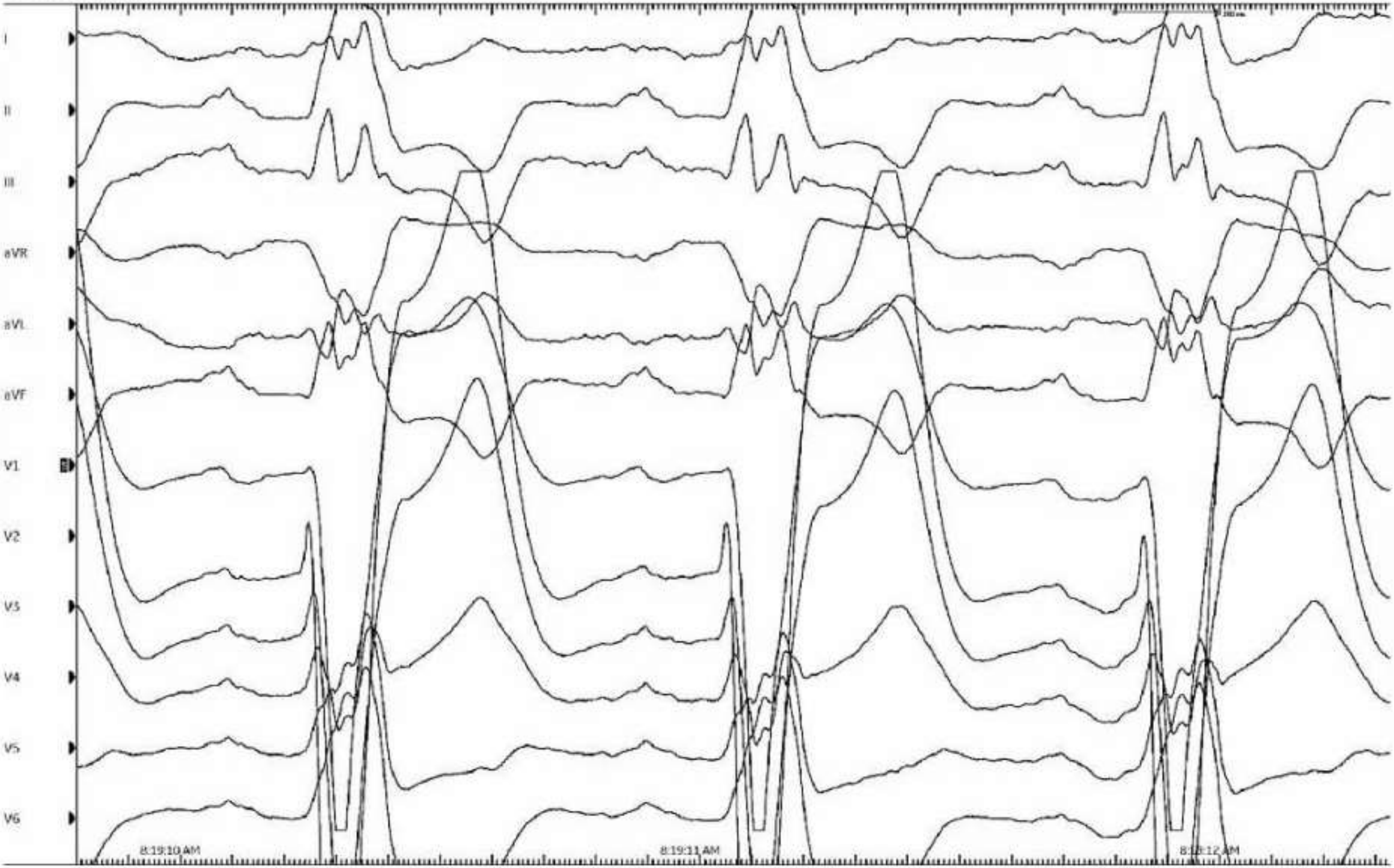
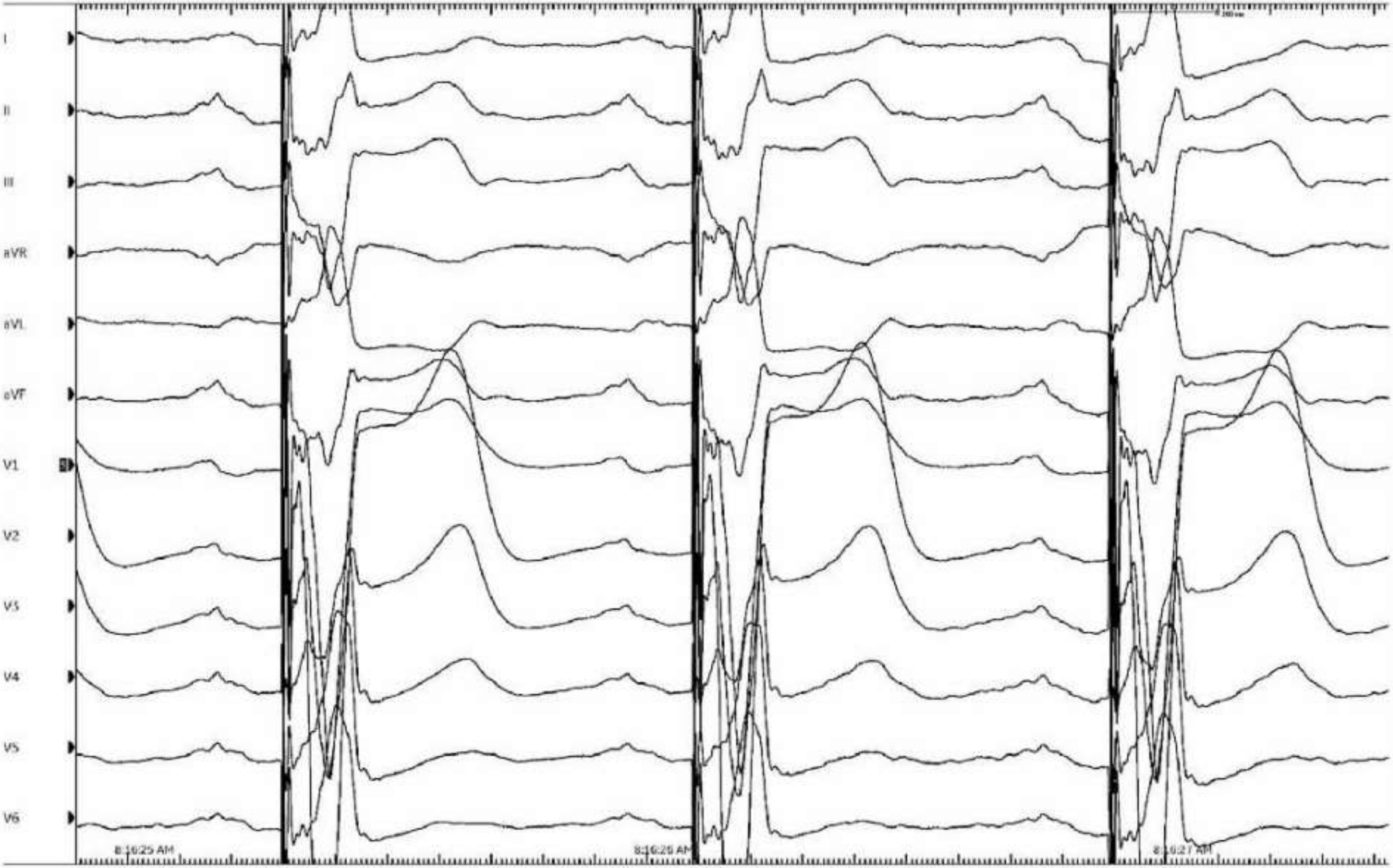
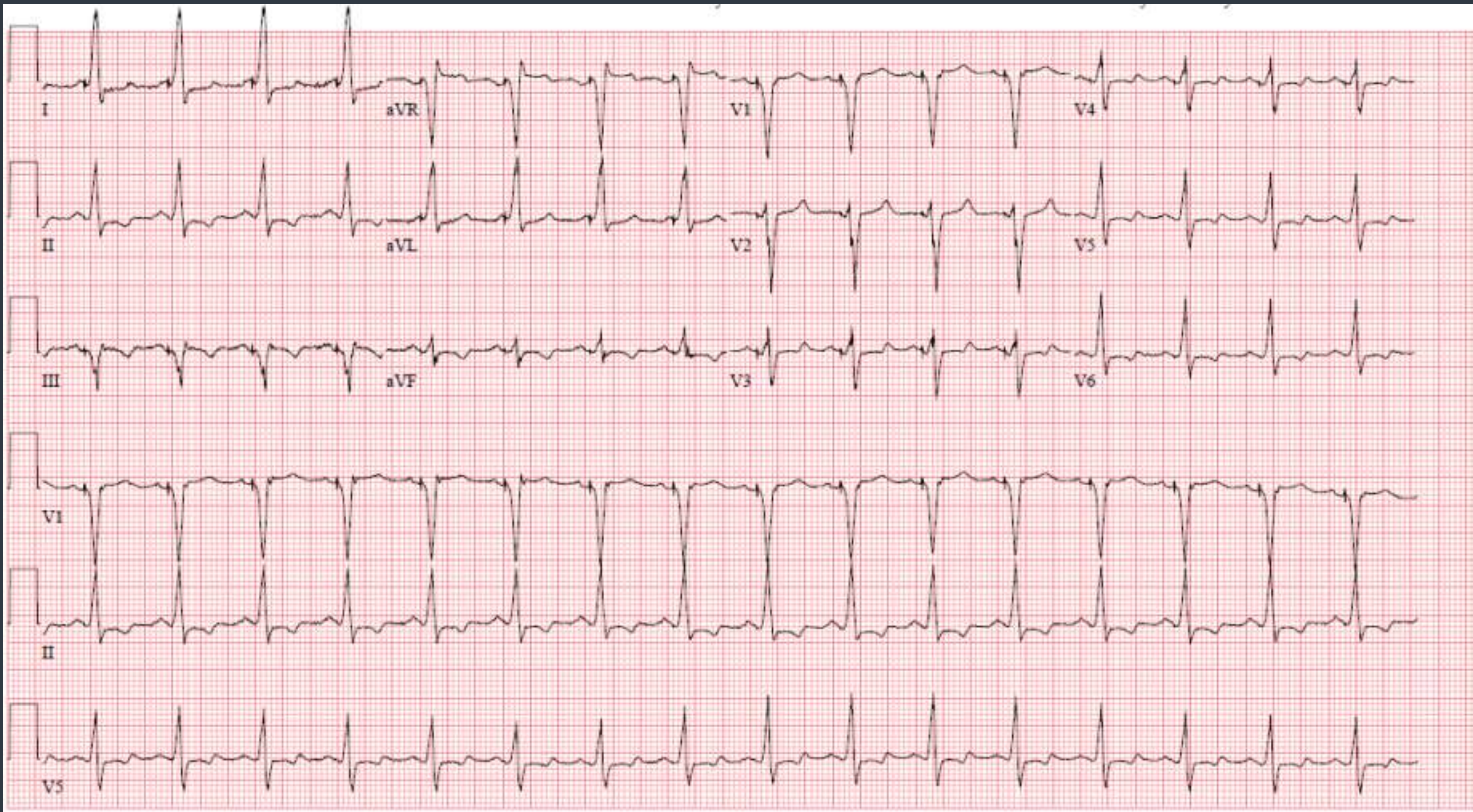

3
Default In
74.2kV, - mAs, 799n
Zo
.2°
WW 256
WL 128
08

3
Default In
72.3kV, - mAs, 695n
Zo
.4°
WW 256
WL 128
08

Underlying



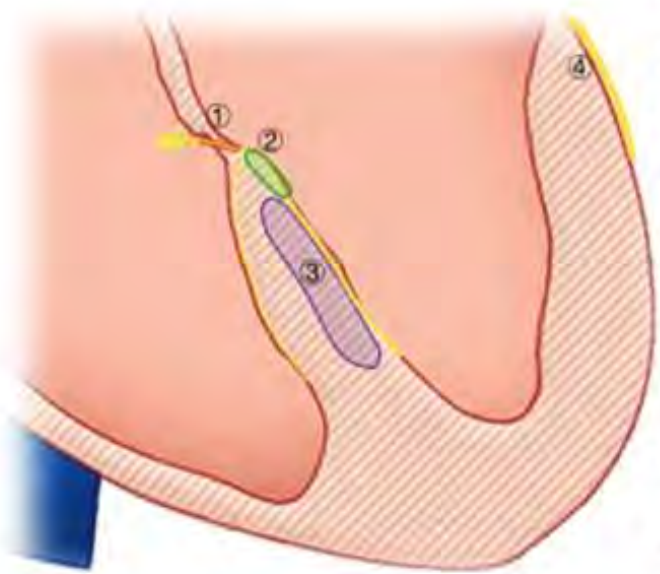
LV only pacing




I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
II
V5


Left

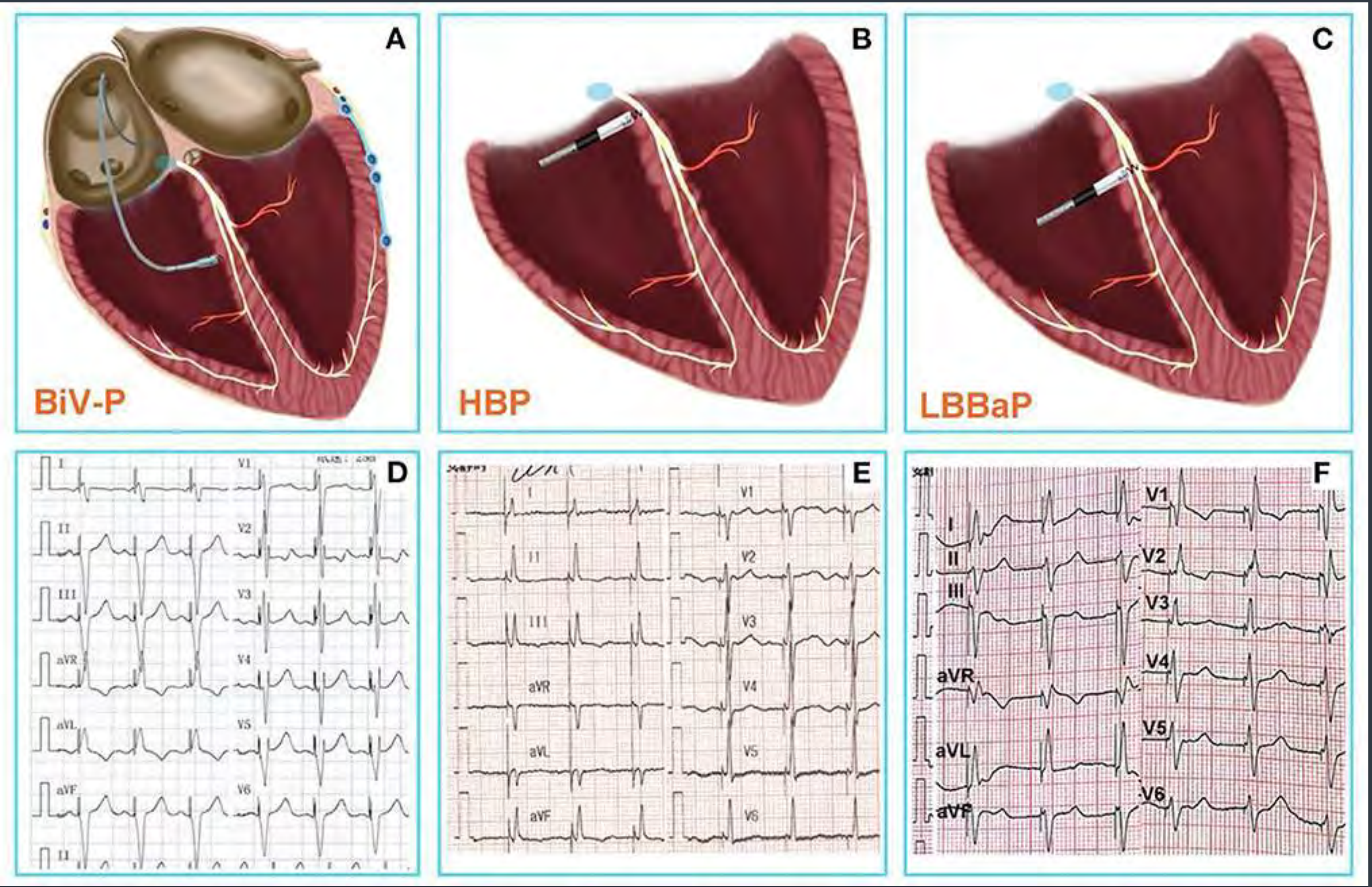
Figure 1: Sites for Conduction System Pacing and Cardiac Resynchronisation Therapy



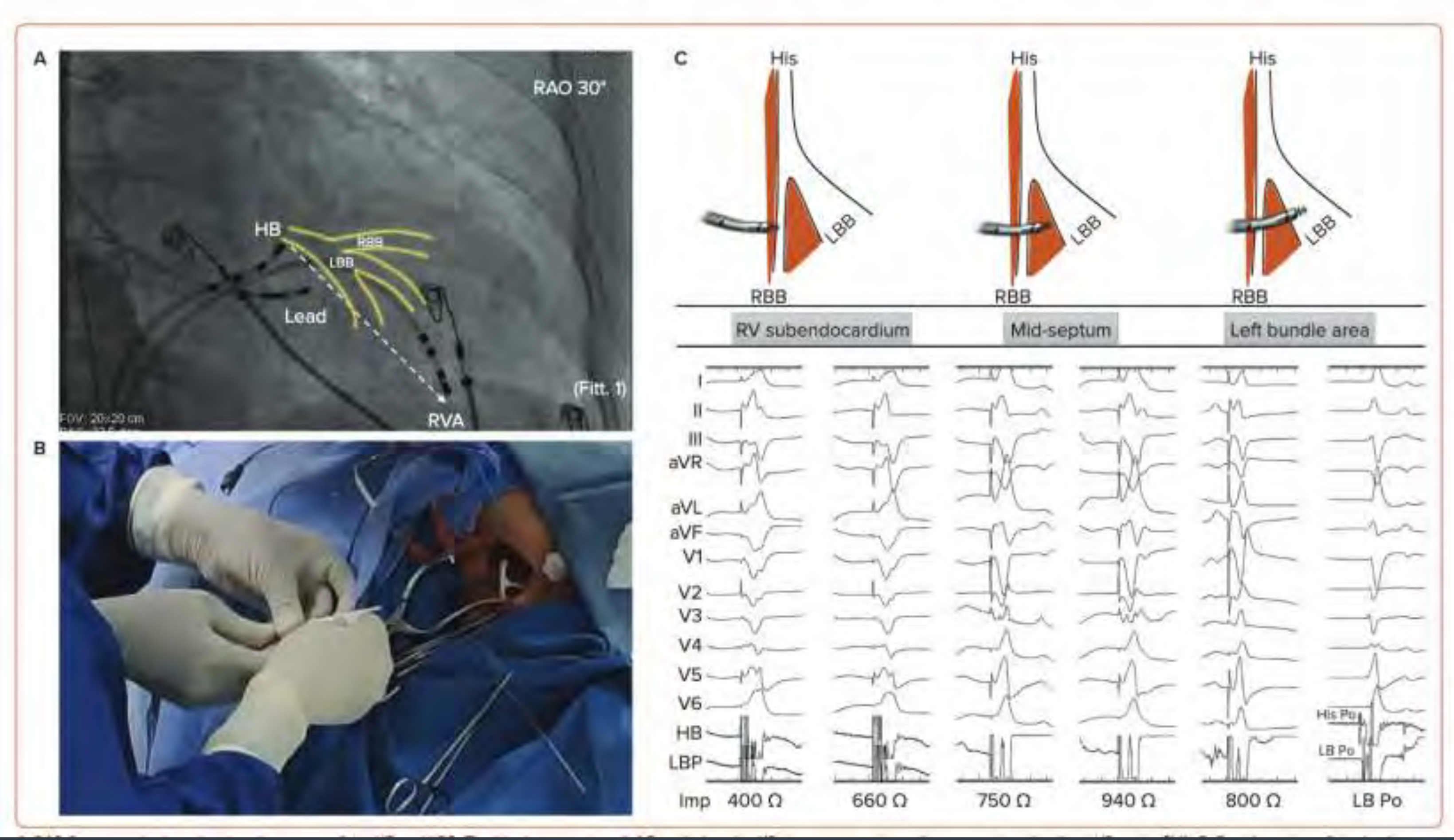
1. His bundle pacing
2. Left bundle branch pacing
3. Left septal pacing
4. LV epicardial pacing

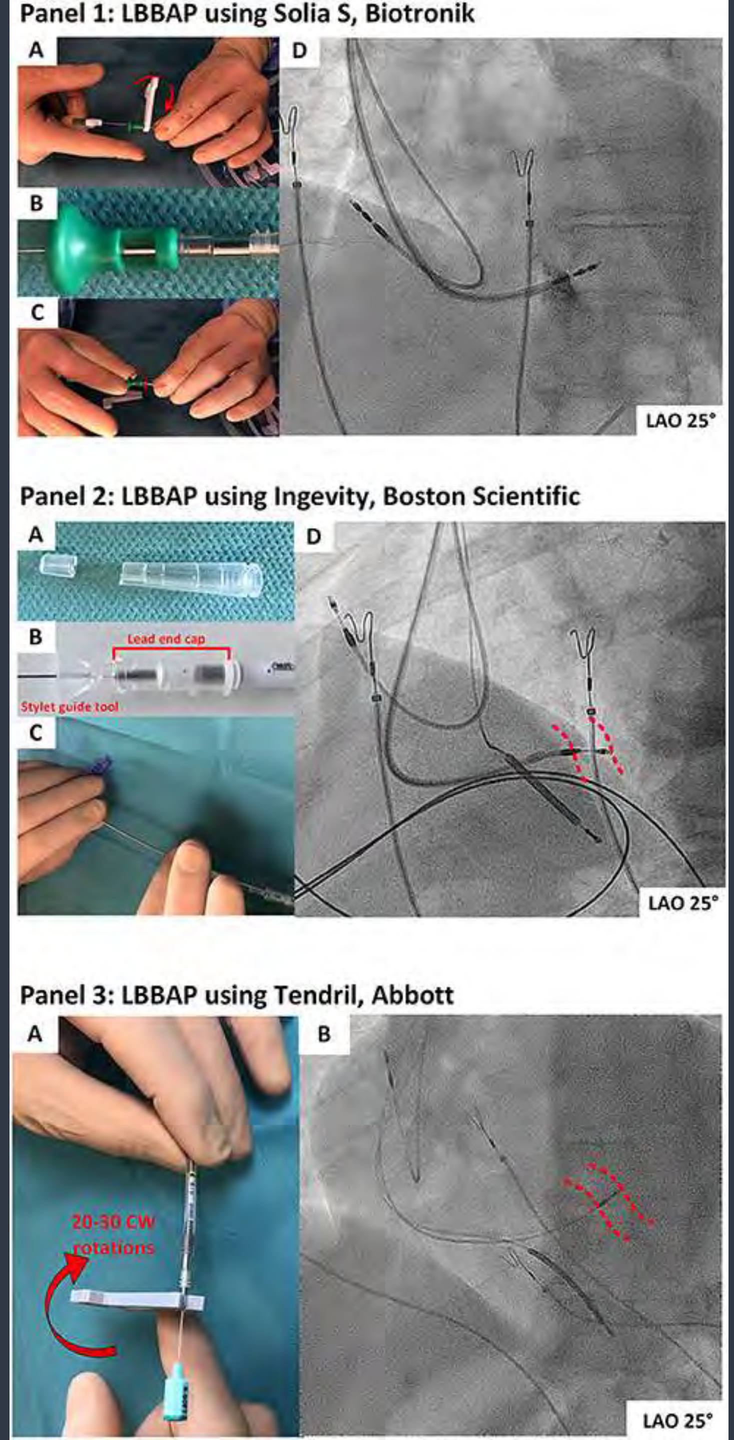
Possible CRT strategies:

1. HBP-CRT = site 1
2. LBBP-CRT = site 2
3. BVP-CRT = site 4 and RV endocardium
4. HOT-CRT = site 1 and 4
5. LOT-CRT = site 2 and 4

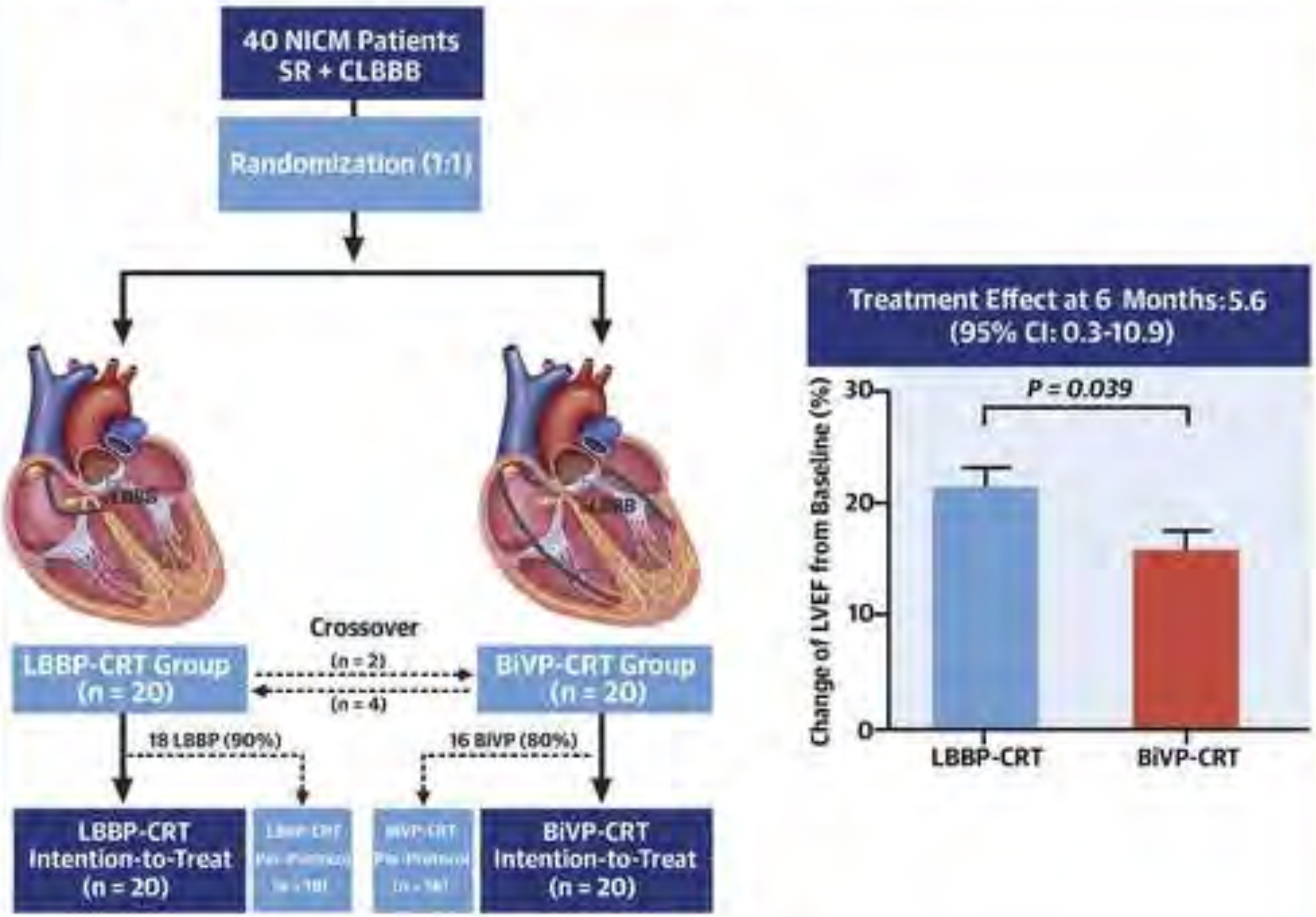

A
B
C
BiV-P
HBP
LBBaP
D
E
F
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6

Left Bundle Branch Area Pacing




Panel 1: LBBAP using Solia S, Biotronik
A
D
B
C
LAO 25°
Panel 2: LBBAP using Ingevity, Boston Scientific
A
D
B
Lead end cap
Stylet guide tool
C
LAO 25°
Panel 3: LBBAP using Tendril, Abbott
A
B
20-30 CW
rotations
LAO 25°

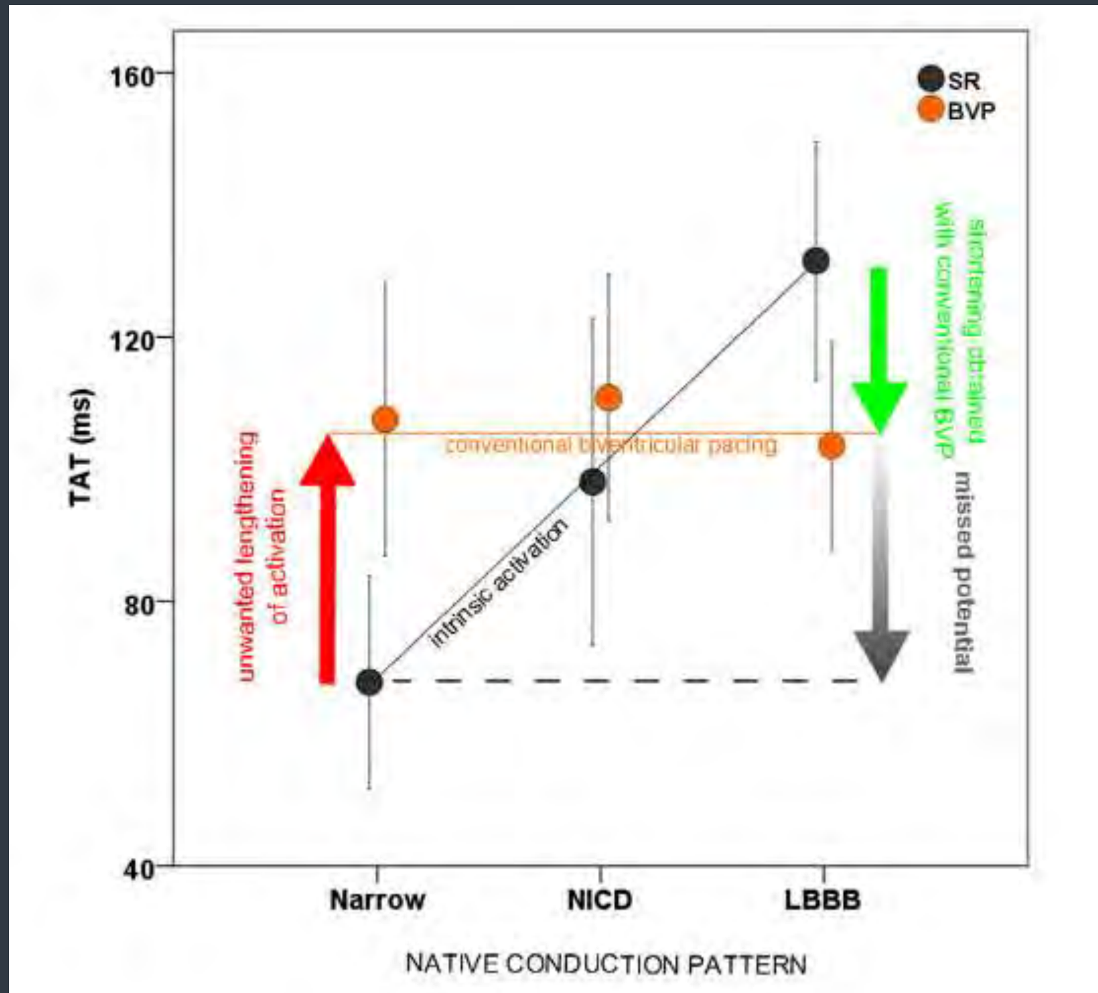
CENTRAL ILLUSTRATION: Left Bundle Branch Pacing vs Biventricular Pacing for cardiac Resynchronization Therapy



Wang Y, et al. J Am Coll Cardiol. 2022;80(13):1205-1216.

Patients who benefit from conduction system pacing

- CSP is useful in HF patients who meet the criteria for CRT; however, it cannot be achieved with Bi-V Pacing
- Some physicians are using CSP as 1st line in these patients
    - The data for traditional CRT, however, is more robust.
- Bi-V Pacing is not as useful in patients with EF > 35% unless they require pacing for bradycardia
    - Growing data for use of CSP in these group
- BI-V Pacing is not as useful for patient with Non LBBB QRS widening
    - Again groin data for the use of CSP is growing



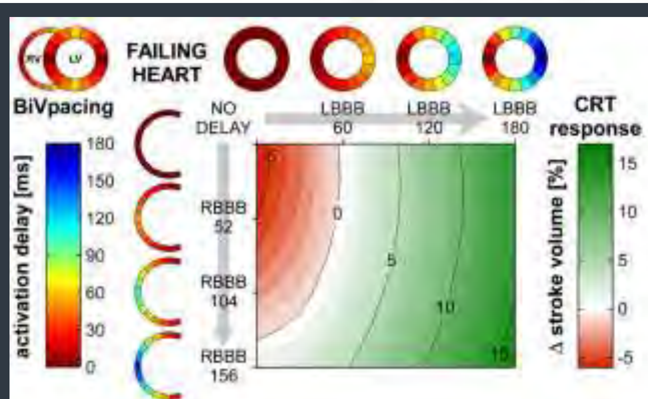
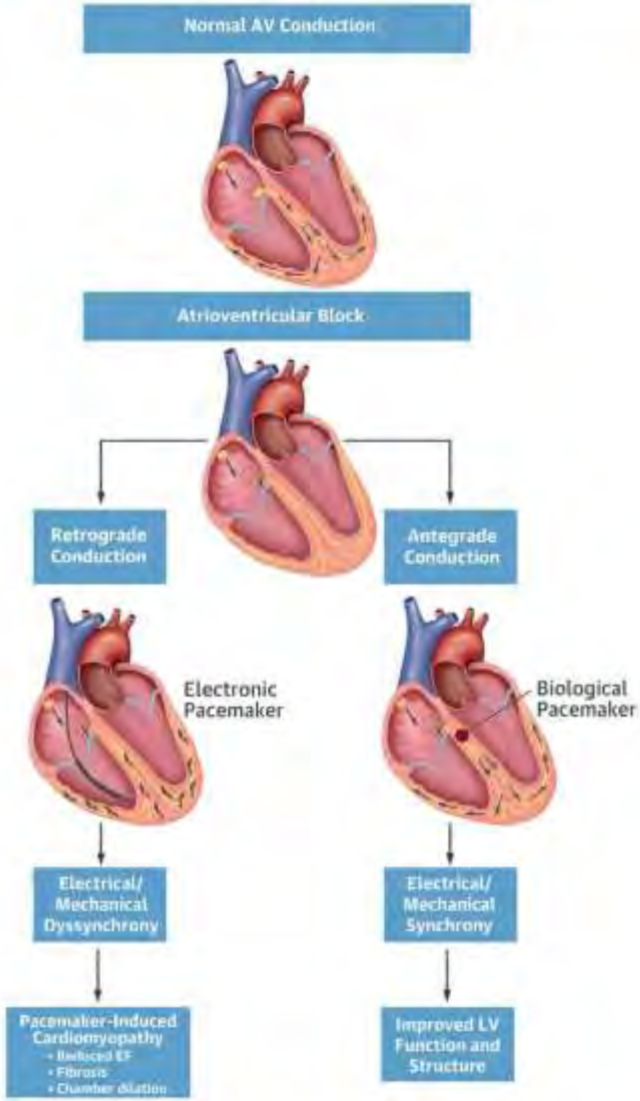


Figure 3. Acute hemodynamic response to conventional biventricular (BiV) pacing in various computer simulations of a failing heart with synchronous ventricular activation, right bundle branch block (RBBB), left bundle branch block (LBBB), or a combination of RBBB and LBBB. Note that cardiac resynchronization therapy (CRT) hardly improves or even deteriorates cardiac pump function in hearts with RBBB in the absence of sufficient coexistent left ventricular (LV) activation delay. RV indicates right ventricular; and RVA, right ventricular apex.

Pivot to Non HF population

CENTRAL ILLUSTRATION: Proposed Mechanism of Pacemaker-Induced Cardiomyopathy



Dawkins, J.F. et al. J Am Coll Cardiol. 2019;73(13):1673-87.

Right Ventricular Pacing is Imperfect

- Myofibrillar disarray and fibrosis
- Ventricular dysynchrony
- Negative inotropy
- Ventricular dilatation
- **Atrial fibrillation**
- **Heart failure**

As little as 20% RV pacing can result in pacing induced cardiomyopathy

The incidence of PICM is around 12%

Pacing Mode Trials

Danish Pacemaker Study
Andersen HR, et al. Lancet 1997;350:1210-16 AAI vs. VVI for SSS Danish pacemaker study: **AAI had slightly better survival and was associated with lower occurrence of CHF** (native AV conduction is better)

CTOPP Study
Patients undergoing first IPG implant, n=2,568 32 Canadian centers, Prospective, randomized

The PAVE Study
J. Cardiovascular, Electrophysiology 2005 Nov;16(11):1160-5
Left Ventricular-Based Cardiac Stimulation Post AV Nodal Ablation Evaluation

MOST Trial
Sweeney M, et al. PACE 2002;25:690
(mode selection trial in sinus-node dysfunction) **Hospitalization was not associated with mode but with prevalence of more then 40% RV pacing**

DAVID Trial
JAMA 2002;288:3115-23
RV stimulation may be more deleterious in patients with advanced LV dysfunction (ICD candidates); DDDR-70 was worse than VVI-40; more pacing (60%) was seen in DDDR-70; however, only 30.8% of the patients had a QRS>130ms

MOST Sub-Study
There was a **strong association between RV pacing and risk of heart failure hospitalizations as well as atrial fibrillation (AF) episodes**

Effects of Chronic RVA Pacing

- Retrospective Analysis of 1,128 patients with moderate LV dysfunction
- Multivariable analysis to determine factors associated with worsening EF

- The strongest independent predictor of LVEF decrease was the presence of a permanent RV apical pacemaker OR 6.6, p=0.002

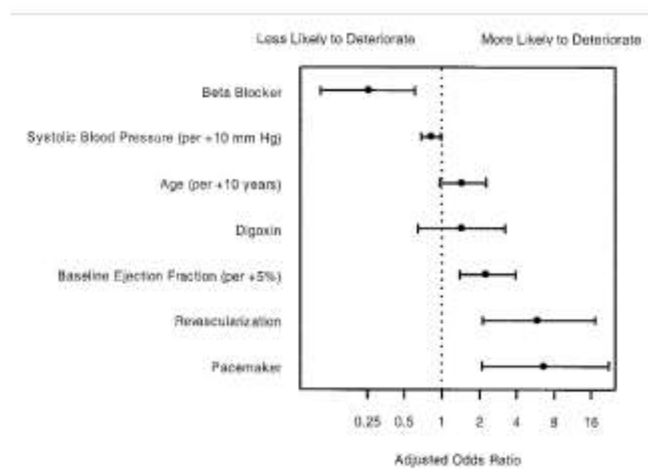
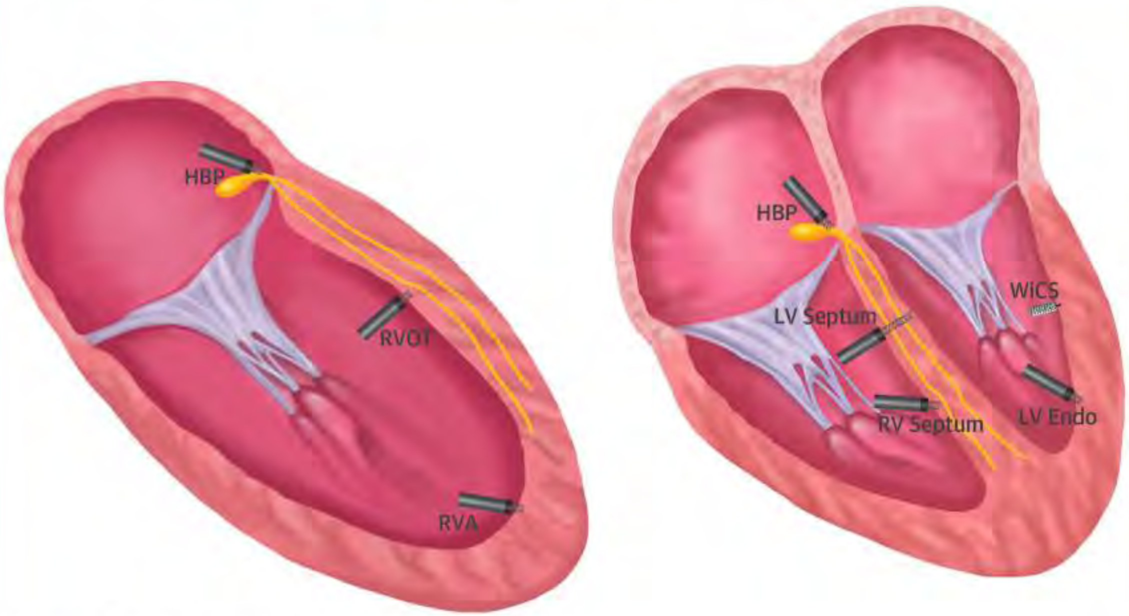


FIGURE 2. Multivariable predictors of deterioration of LV function. Age odds ratio per 10-year increase. Systolic blood pressure per 10-mm Hg increase.

Fig. 2. Light micrograph demonstrating myofibril disarray in myocardial tissue obtained from the left ventricular base of a dog placed in heart block and electronically paced for 3 months. Note that the myofibrils below the nucleus *(N)* intersect at 90 degrees with the fibril immediately left of the nucleus. Intercalated discs are indicated *by arrows*. (One micron Epon section stained with methylene blue; original magnification ×1000.)

O'Keefe, JH et al. 2005. Effect of chronic right ventricular apical pacing on left ventricular function. *The American journal of …*. (2005).

CENTRAL ILLUSTRATION Alternative Pacing Sites to Mimic Physiological Pacing



Vijayaraman, P. et al. J Am Coll Cardiol. 2017;69(25):3099–114.

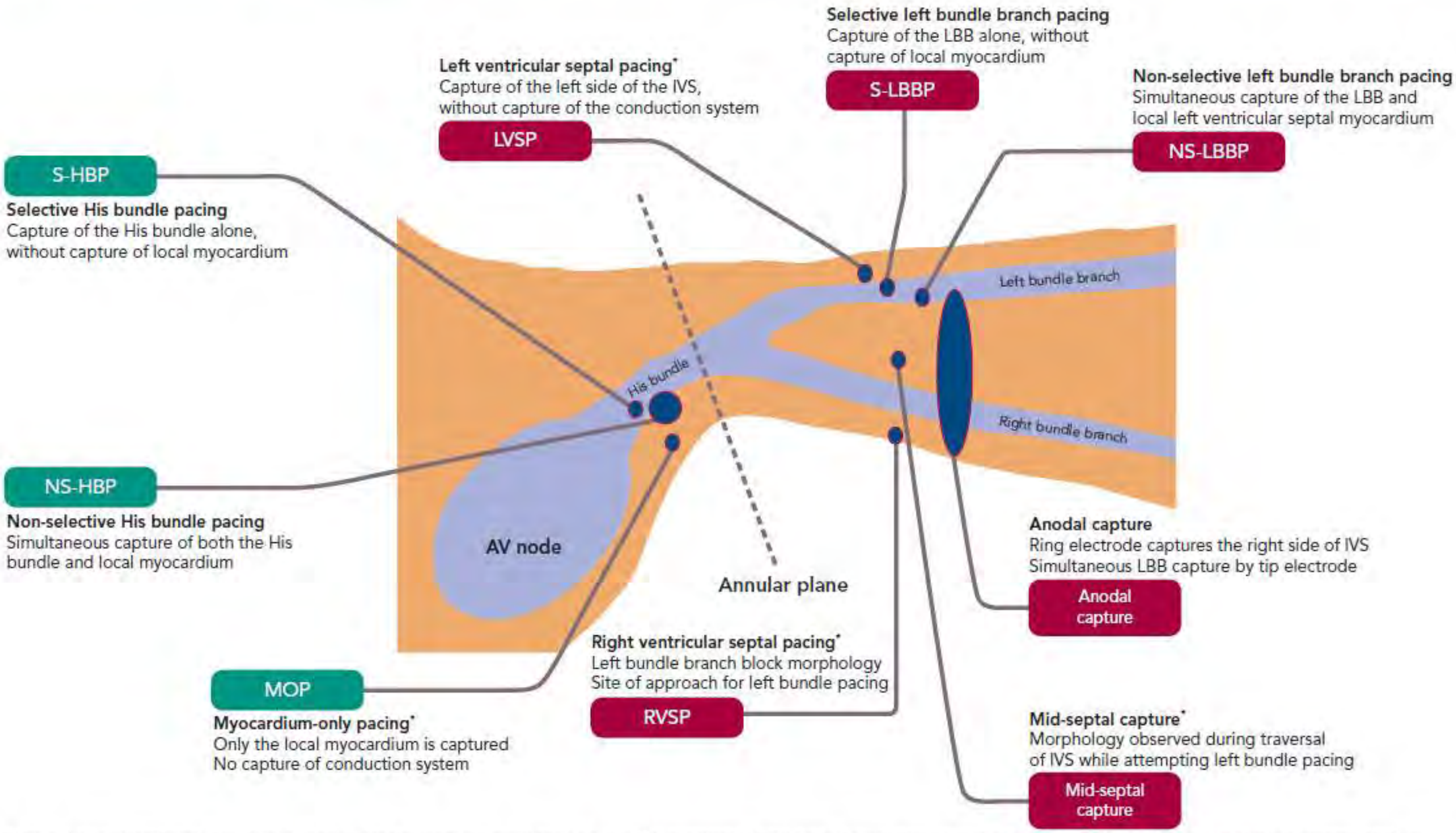
Various pacing sites have been evaluated in the past to reduce ventricular dyssynchrony induced by right ventricular apical pacing. Newer pacing options, such as His-bundle pacing, LV septal pacing, and LV endocardial pacing require further evaluation. Endo = endocardial; HBP = His-bundle pacing; LV = left ventricular; RV = right ventricular; RVA = right ventricular apical; RVOT = right ventricular outflow tract; WiCS = Wireless cardiac stimulation.

Right Ventricular Pacing Should be minimized or Avoided

Strategies

1. Alternative Site Pacing
2. Programming to minimize RV pacing
   - **a.** **AAI** programming
   - b. DDD pacing with a **fixed long AV delay**
   - c. Search **AV hysteresis** algorithms
     1. AV search+ (Boston Sci)
   - d. Algorithms based on the **AAI/DDD mode switch**
     1. Managed ventricular pacing (MVP Mode, Medtronic)
     2. Ventricular Intrinsic Preference (VIP Mode, SJM)
     3. RHYTHMIQ (Boston Sci)

Figure 1: Conduction System Pacing



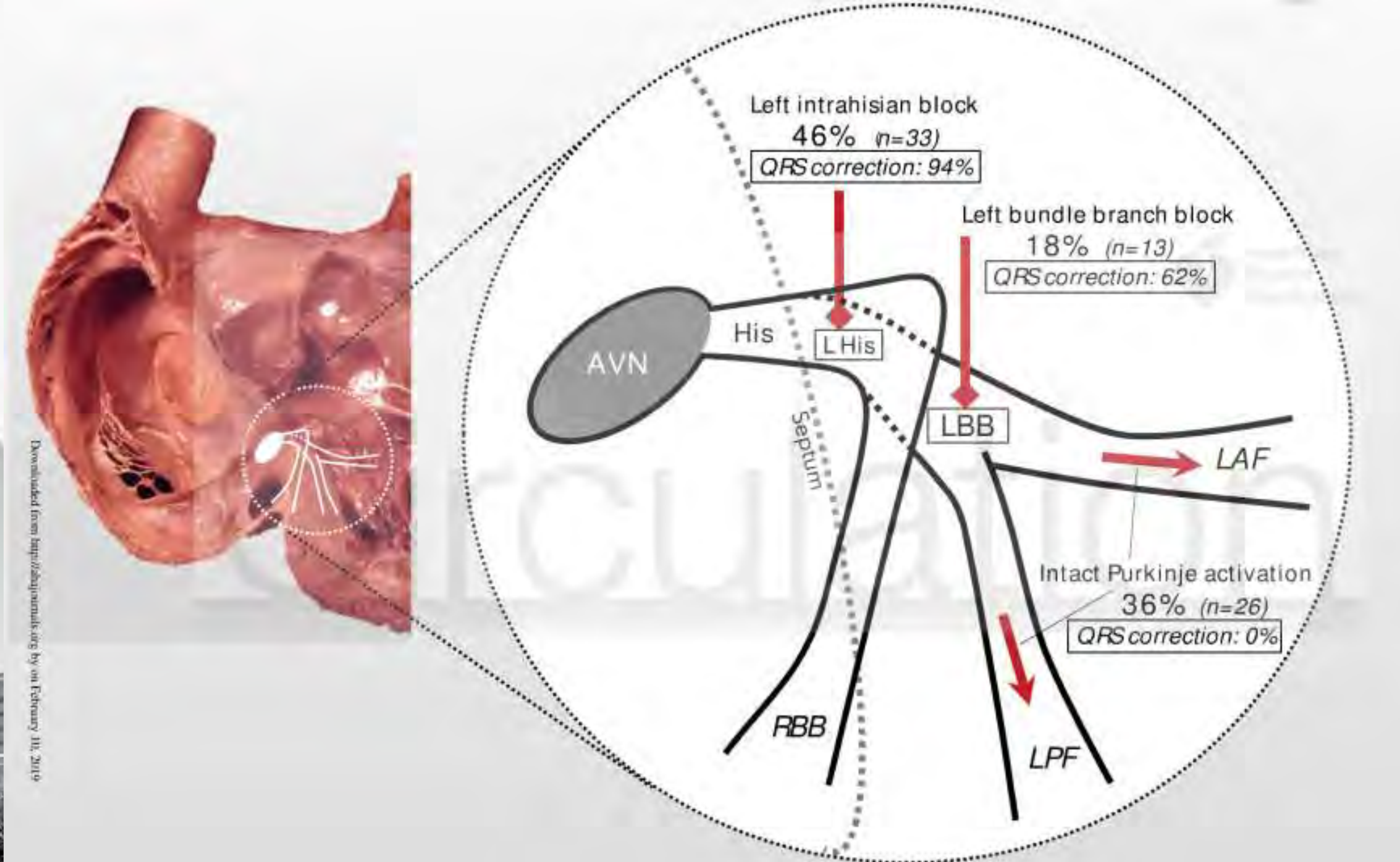
*Terminology and captured structures during attempted conduction system pacing. Blue represents the conduction system while myocardium and membranous septum are represented in orange. Blue circles represent the functional virtual electrode in different kinds of pacing. In green are capture morphologies seen during attempted His bundle pacing. In red are capture morphologies seen in left bundle branch area pacing. *Direct conduction system capture does not occur (but delayed penetrance into the conduction system may be possible).*
IVS = interventricular septum; LBB = left bundle branch; LVSP = left ventricular septal pacing ; MOP = myocardium-only pacing; NS-HBP = non-selective His bundle pacing; NS-LBBP = non-selective left bundle branch pacing; RVSP = right ventricular septal pacing S-HBP = selective His bundle pacing; S-LBBP = selective left bundle branch pacing.

Potential benefits of His Bundle pacing

His Bundle Pacing presents a potential option

1. Replicates human physiologic conduction; His–Purkinje activation causes synchronous activation and contraction of the ventricles and preserved LV function.
2. Maintains AV **and** VV synchrony
3. Lead body potentially all within the RA (potentially limiting issues with pacing lead related TR)

Permanent HB pacing originally described by Deshmukh P et. Al in 2000


Left intrahisian block
46% (n=33)
QRS correction: 94%
Left bundle branch block
18% (n=13)
QRS correction: 62%
AVN
His
L His
LBB
Septum
LAF
Intact Purkinje activation
36% (n=26)
QRS correction: 0%
RBB
LPF

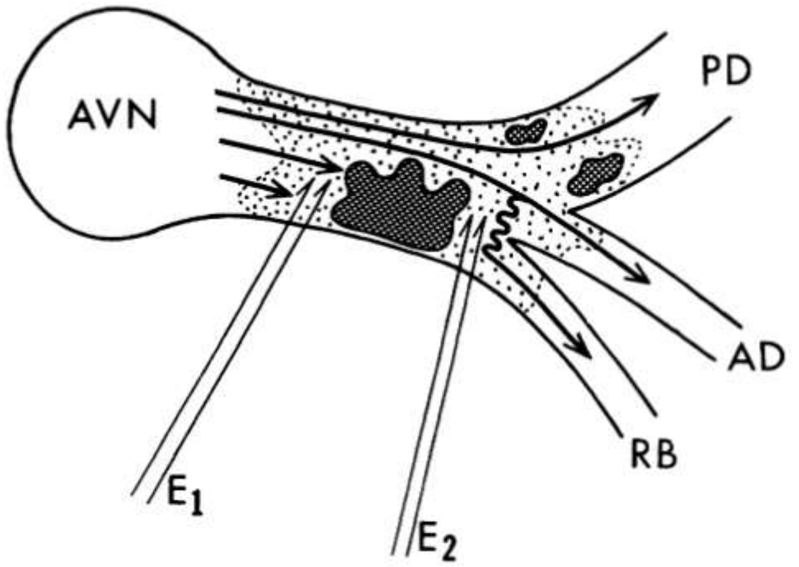


FIGURE 8. *A schematic illustration of functional longitudinal dissociation in the ischemic His bundle that could result in a right bundle branch block pattern. AVN, atrioventricular node; RB, right bundle branch; AD, anterior division of left bundle; PD, posterior division of the left bundle; E_1 and E_2, plunge wire electrodes in the proximal and distal His bundle respectively.*

Injury to the HB trunk can damage these fibers, resulting in asynchronous HB activation and an ECG of bundle branch block (BBB), fascicular block, or complete AV block.

His bundle pacing (HBP) refers to electrical excitation of any part of the atrioventricular (AV) junction resulting in ventricular activation exclusively over the His-Purkinje system.

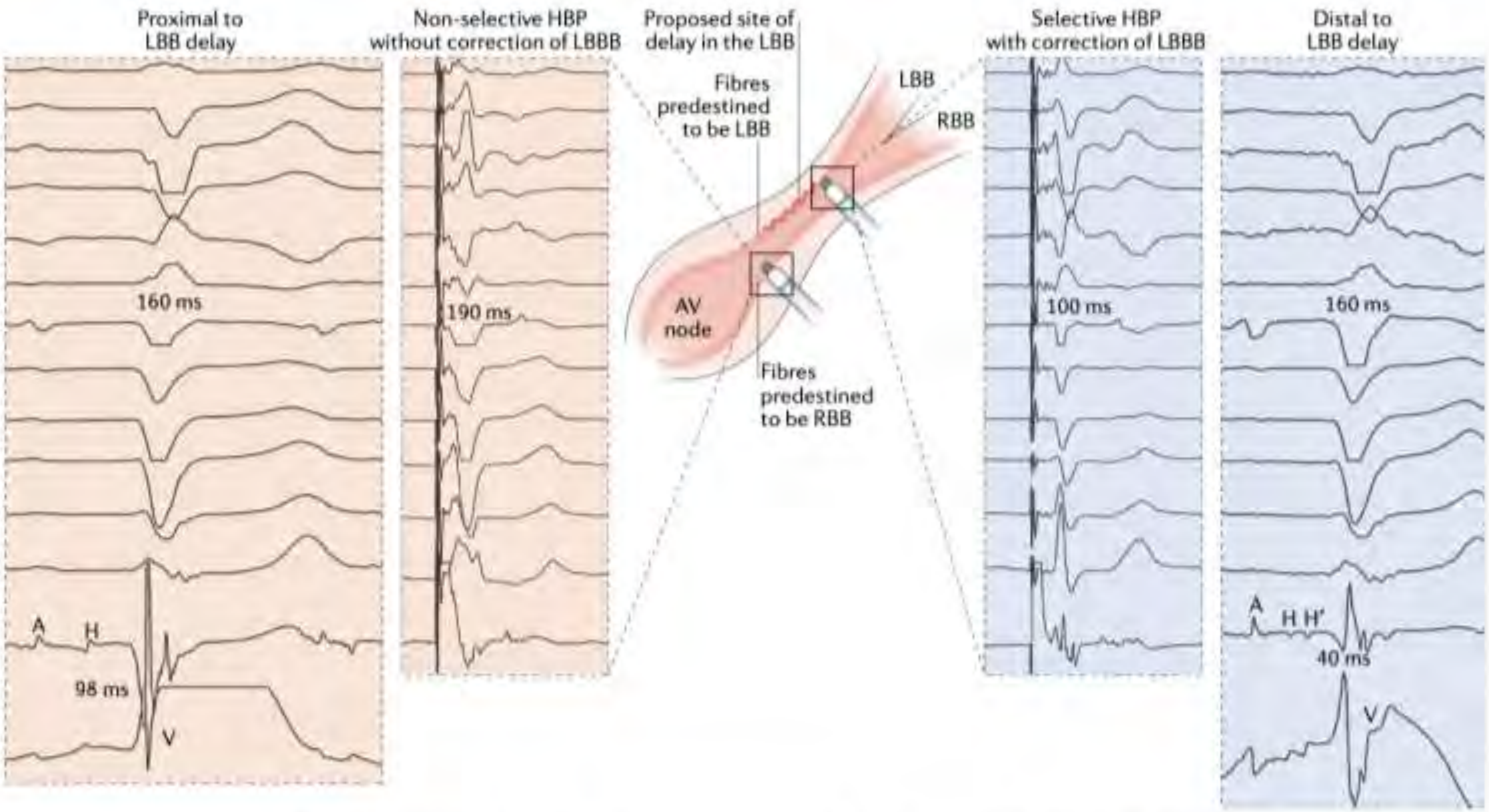
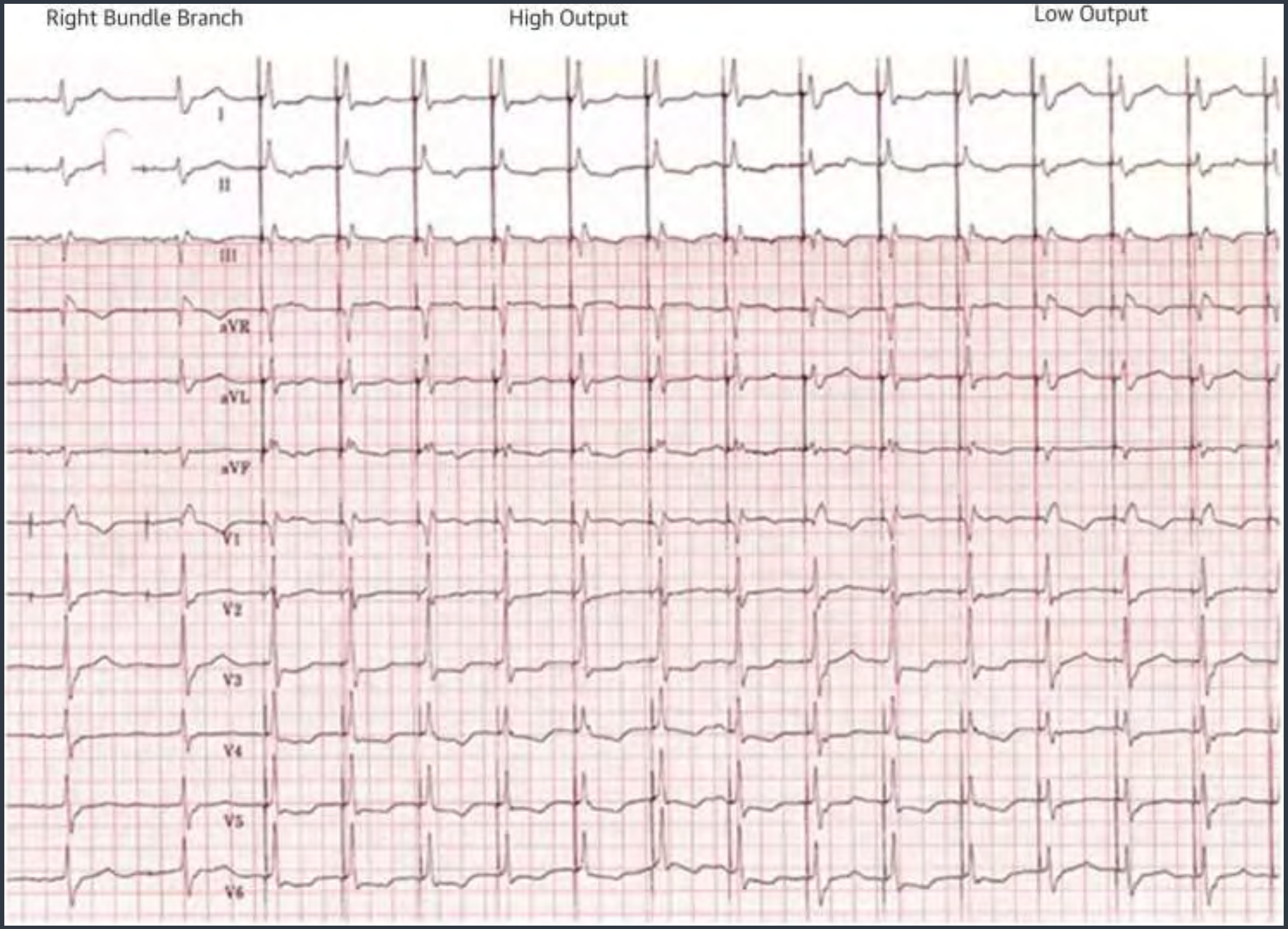


Fig. 2 | **Longitudinal dissociation within the His bundle.** Proposed model of longitudinal dissociation in the His bundle is depicted in the centre of the figure, demonstrating fibres predestined for either the right bundle branch (RBB) or the left

Longitudinal dissociation



SPECIFICATIONS

SelectSecure™ 3830 Lead

Physical Characteristics

Polarity	Bipolar
Shape	Straight
Chamber	Ventricle or Atrium
Standard Lengths	49, 59, 69, 74 cm
Connector	IS-1 BI

Materials

Insulator	Polyurethane (outer), Silicone and ETFE (inner)
Conductor	MP35N
Helix Electrode	Titanium Nitride Coated Platinum Alloy
Ring Electrode	Titanium Nitride Coated Platinum Alloy

Diameter

Body	1.4 mm (4.1 Fr)

Electrode Configuration

Fixed Helix Screw

Electrode Surface Area

Helix	3.6 mm^2
Ring	16.9 mm^2

Helix Length

1.8 mm

a

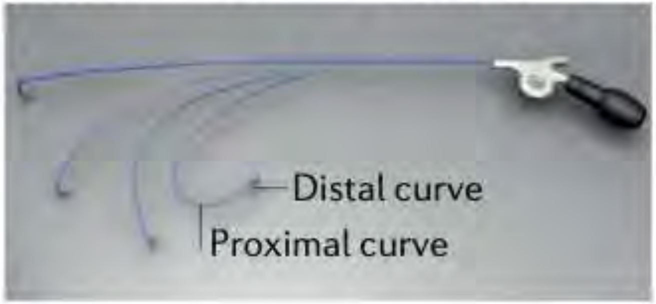
C315 HIS sheath

- Outer diameter 7.0 F
- Inner diameter 5.4 F

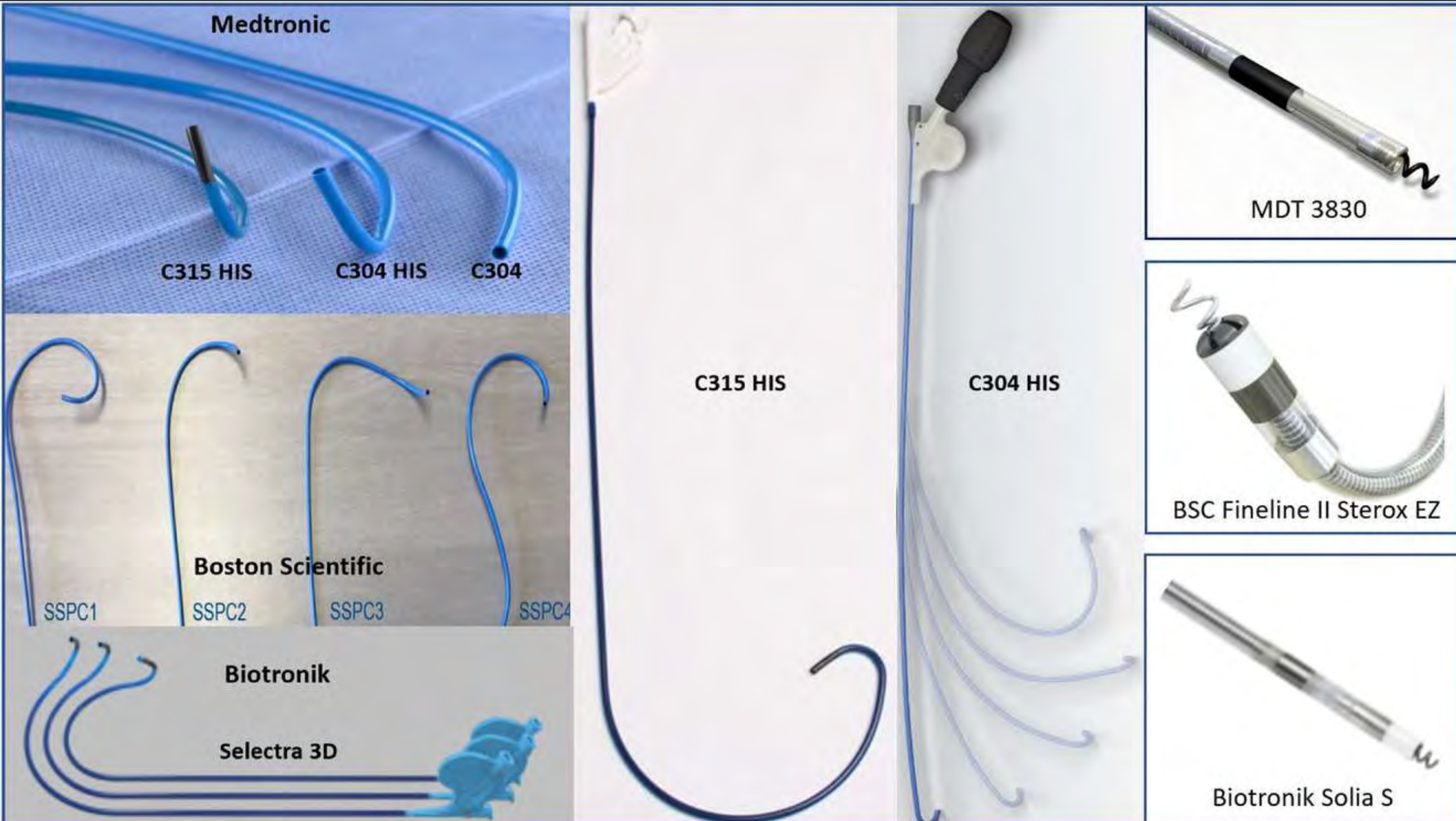
SelectSecure 3830 pacing lead

- 4.1 F, exposed helix
- Isodiametric lead body
- Lumenless design

SelectSite C304 HIS deflectable sheath



- Outer diameter 8.4 F
- Inner diameter 5.7 F


Medtronic
C315 HIS
C304 HIS
C304
Boston Scientific
SSPC1
SSPC2
SSPC3
Biotronik
Selectra 3D
C315 HIS
C304 HIS
MDT 3830
BSC Fineline II Sterox EZ
Biotronik Solia S

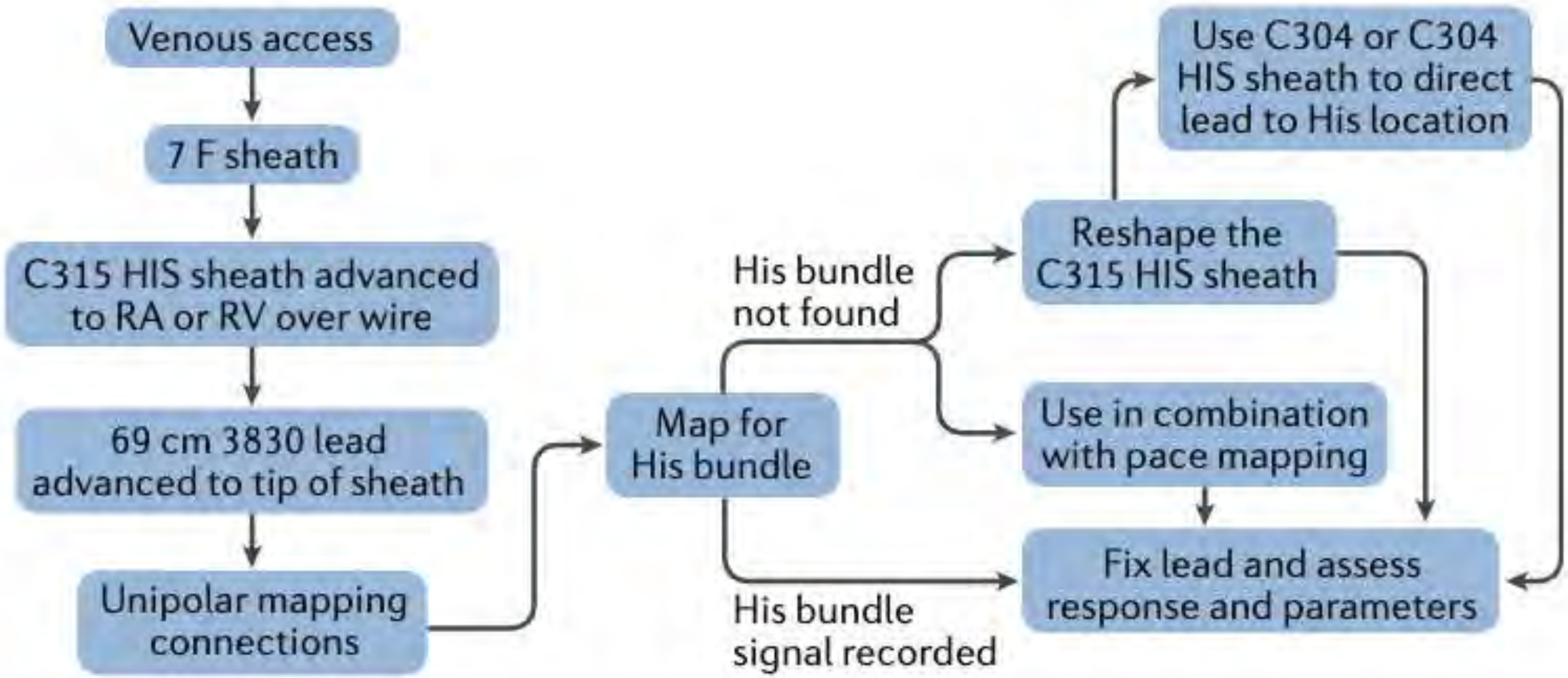
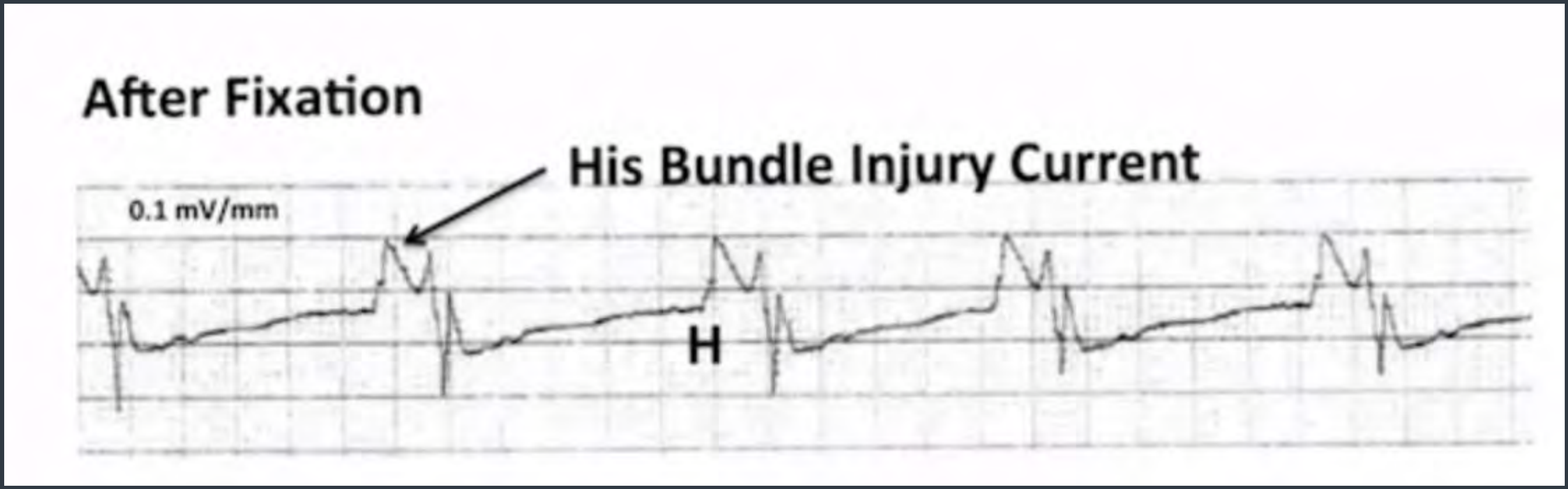
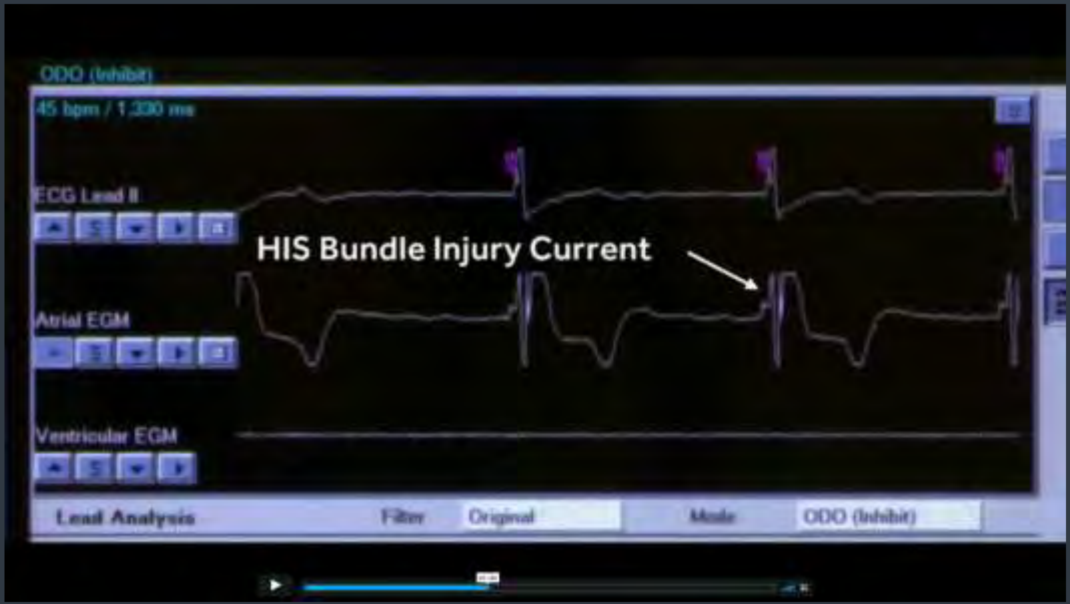


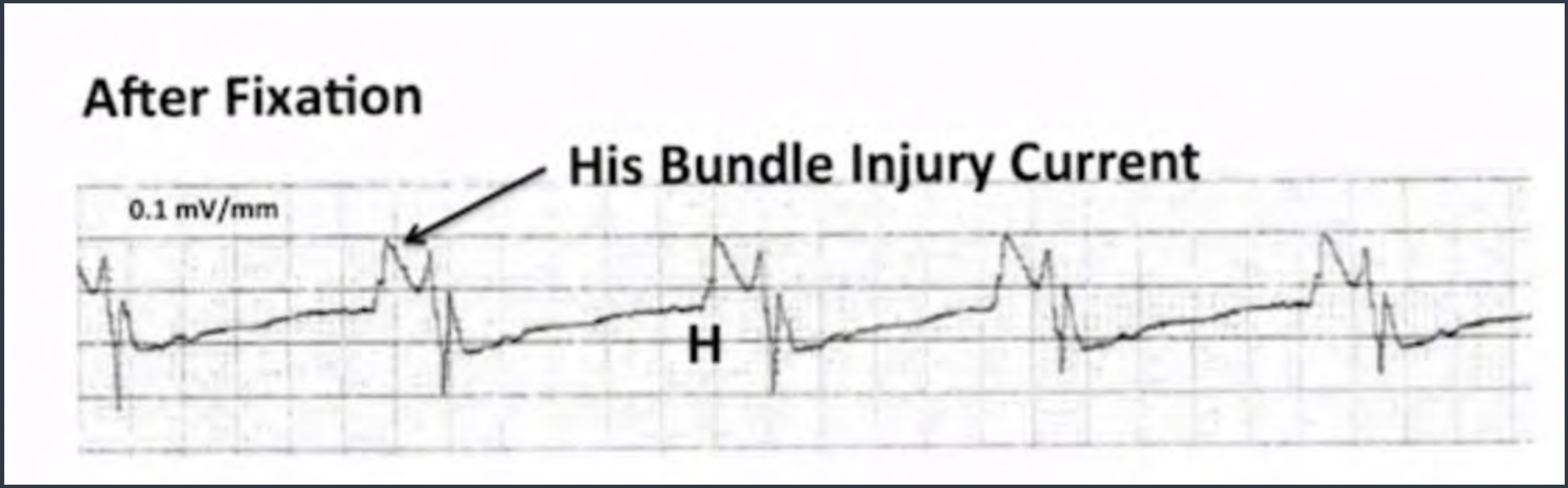
Fig. 4 | **Algorithm for His bundle pacing.** Simplified algorithm for performing His bundle pacing. RA, right atrium; RV, right ventricle.

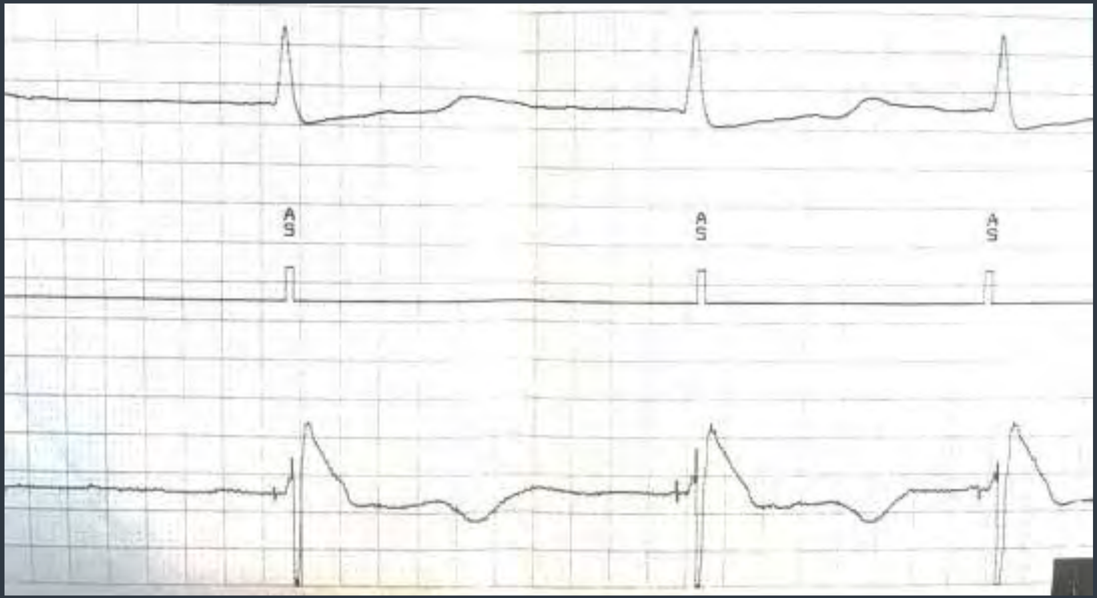
Mapped HIS Potential
ECG Lead II
Atrial EGM
Ventricular EGM
Freeze
Adjust...
Lead Analysis
Filter
Original
Mode

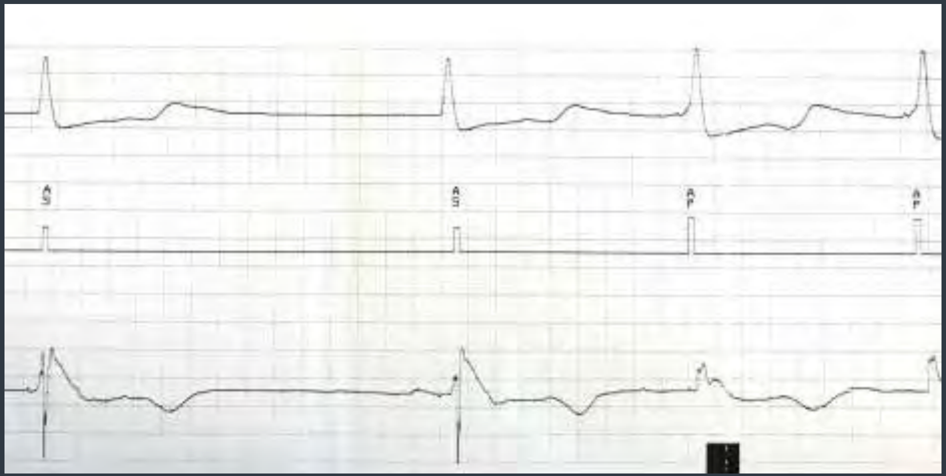


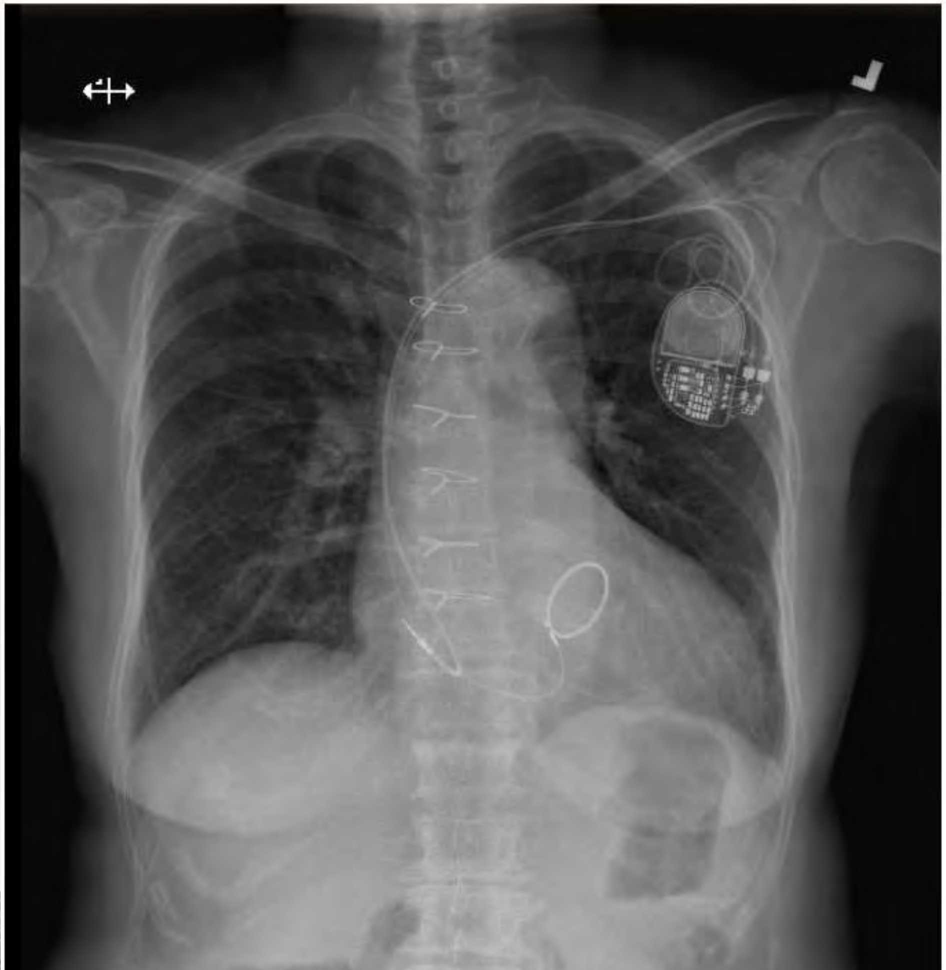
After Fixation
His Bundle Injury Current
0.1 mV/mm
H

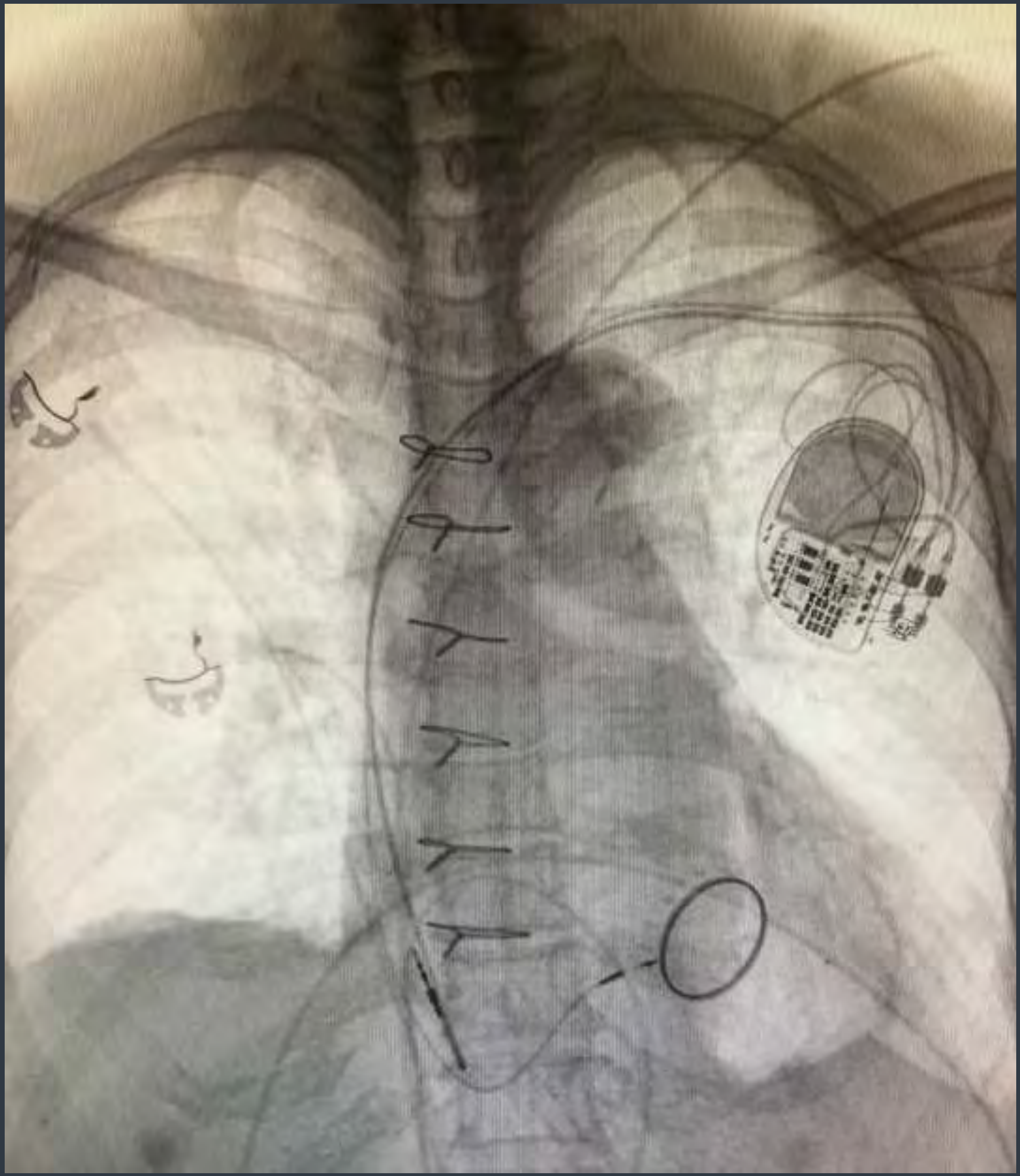

ODO (Inhibit)
ECG Lead II
HIS Bundle Injury Current
Atrial EGM
Ventricular EGM
Lead Analysis
Filter
Original
Mode
ODO (Inhibit)

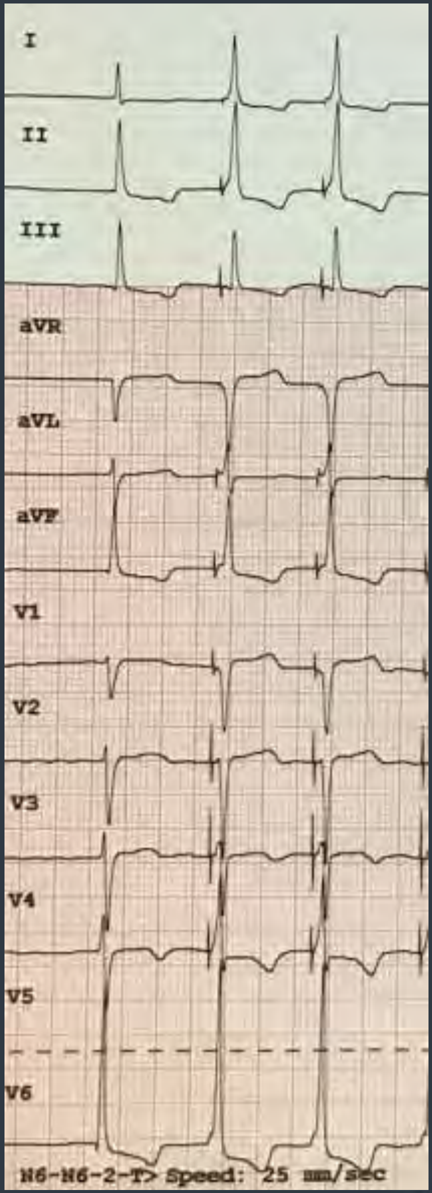

After Fixation
His Bundle Injury Current
0.1 mV/mm
H


AS
AS
AS


AS
AS
AP
AP





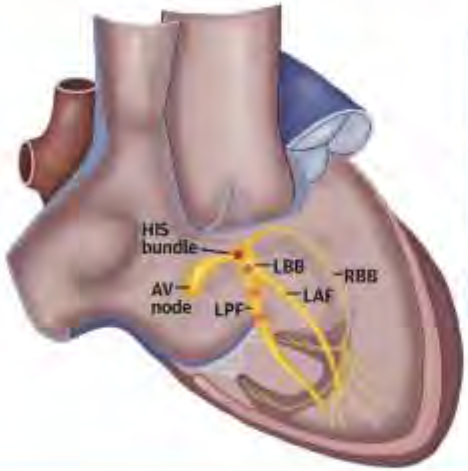

I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
N6-N6-2-T> Speed: 25 mm/sec

CENTRAL ILLUSTRATION: HBP Compared With LBBAP

A

His Bundle Pacing

- Technically challenging
- Narrow target zone
- Encased in electrically inert fibrous tissue
- Low success rates in AV block
- High thresholds



Left Bundle Branch Area Pacing

- Technically less challenging
- Wide target zone
- Encased in dense muscle
- High success rates in AV block
- Low thresholds

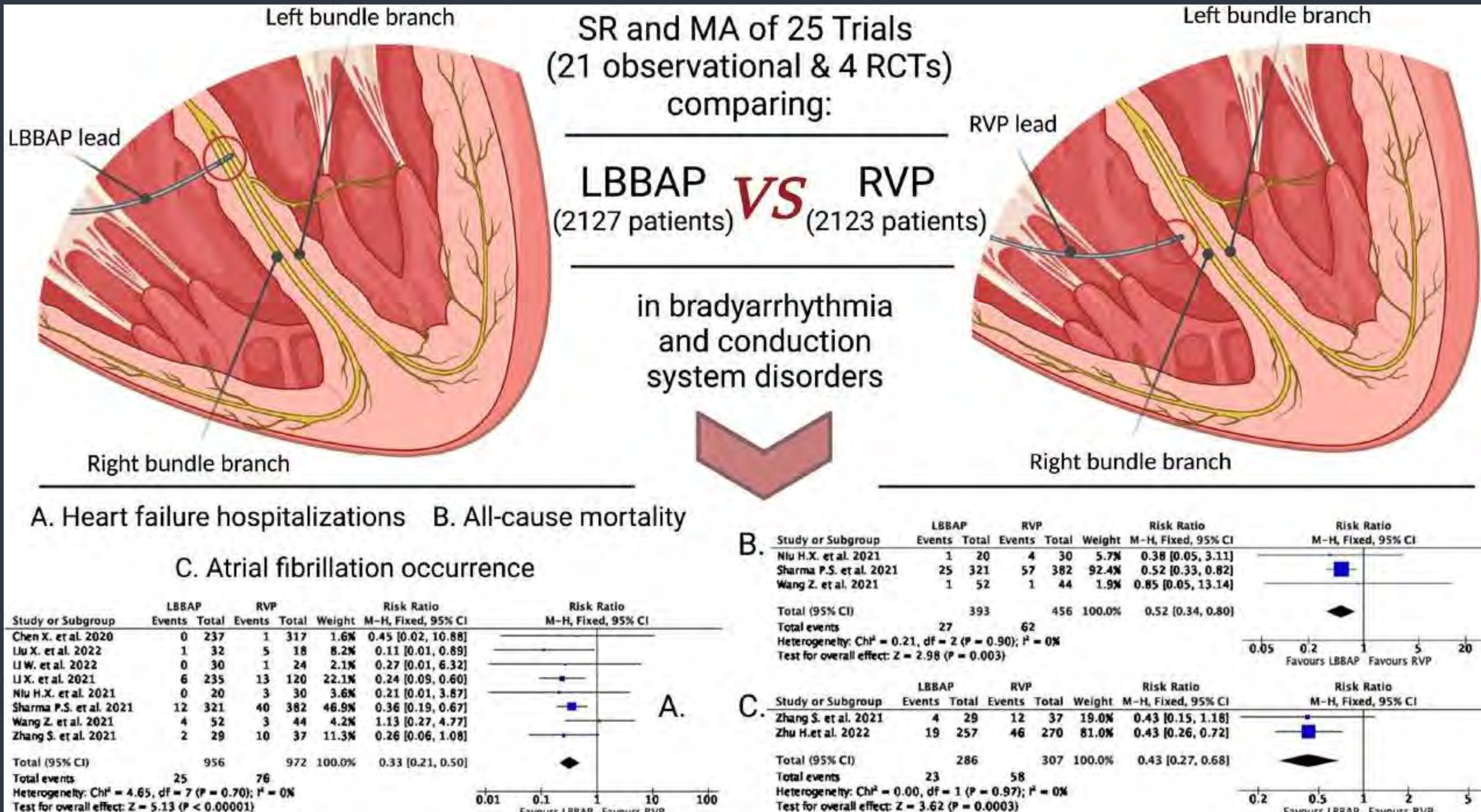
B

Septogram showing lead depth in septum

C

TTE short axis showing lead depth in septum

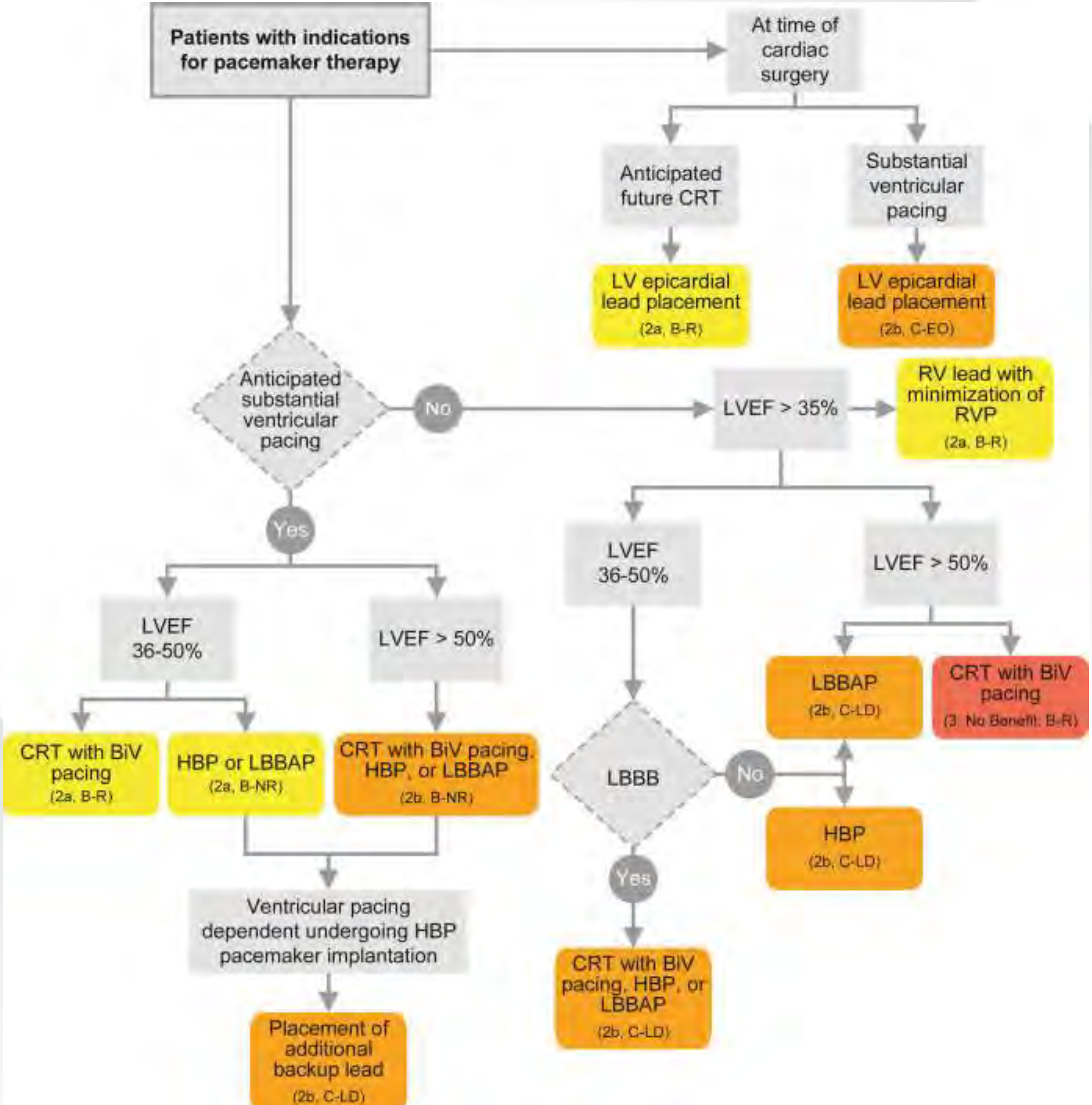
Padala, S.K. et al. J Am Coll Cardiol EP. 2020;6(14):1773-82.



[Safety and efficacy of left bundle branch area pacing compared with right ventricular pacing in patients with bradyarrhythmia and conduction system disorders: a systematic review and meta-analysis]

Patients who benefit from conduction system pacing

- CSP is useful in HF patients who meet the criteria for CRT; however, it cannot be achieved with Bi-V Pacing
- Some physicians are using CSP as 1st line in these patients
    - The data for traditional CRT, however, is more robust.
- Bi-V Pacing is not as useful in patients with EF > 35% unless they require substantial ventricular pacing for bradycardia
    - Growing data for use of CSP in these group
- BI-V Pacing is not as useful for patient with Non LBBB QRS widening
    - Again groin data for the use of CSP
- **<u>Any patient in whom you would consider placing a traditional RV apical Lead</u>**
    - If <20% VP expected (Class IIB)
    - If >20% VP expected (Class IIA)


Patients with indications for pacemaker therapy
At time of cardiac surgery
Anticipated future CRT
Substantial ventricular pacing
LV epicardial lead placement (2a, B-R)
LV epicardial lead placement (2b, C-EO)
Anticipated substantial ventricular pacing
No
LVEF > 35%
RV lead with minimization of RVP (2a, B-R)
Yes
LVEF 36-50%
LVEF > 50%
LVEF 36-50%
LVEF > 50%
CRT with BiV pacing (2a, B-R)
HBP or LBBAP (2a, B-NR)
CRT with BiV pacing, HBP, or LBBAP (2b, B-NR)
LBBB
No
Yes
LBBAP (2b, C-LD)
CRT with BiV pacing (3: No Benefit; B-R)
HBP (2b, C-LD)
Ventricular pacing dependent undergoing HBP pacemaker implantation
Placement of additional backup lead (2b, C-LD)
CRT with BiV pacing, HBP, or LBBAP (2b, C-LD)

References

- Glikson, M. et al. 2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy developed by the Task Force on cardiac pacing and cardiac resynchronization therapy of the European Society of Cardiology (ESC)

- Chung, M. K. *et al.* 2023 HRS/APHRS/LAHRS guideline on cardiac physiologic pacing for the avoidance and mitigation of heart failure. *Hear. Rhythm* **20**, e17–e91 (2023).

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