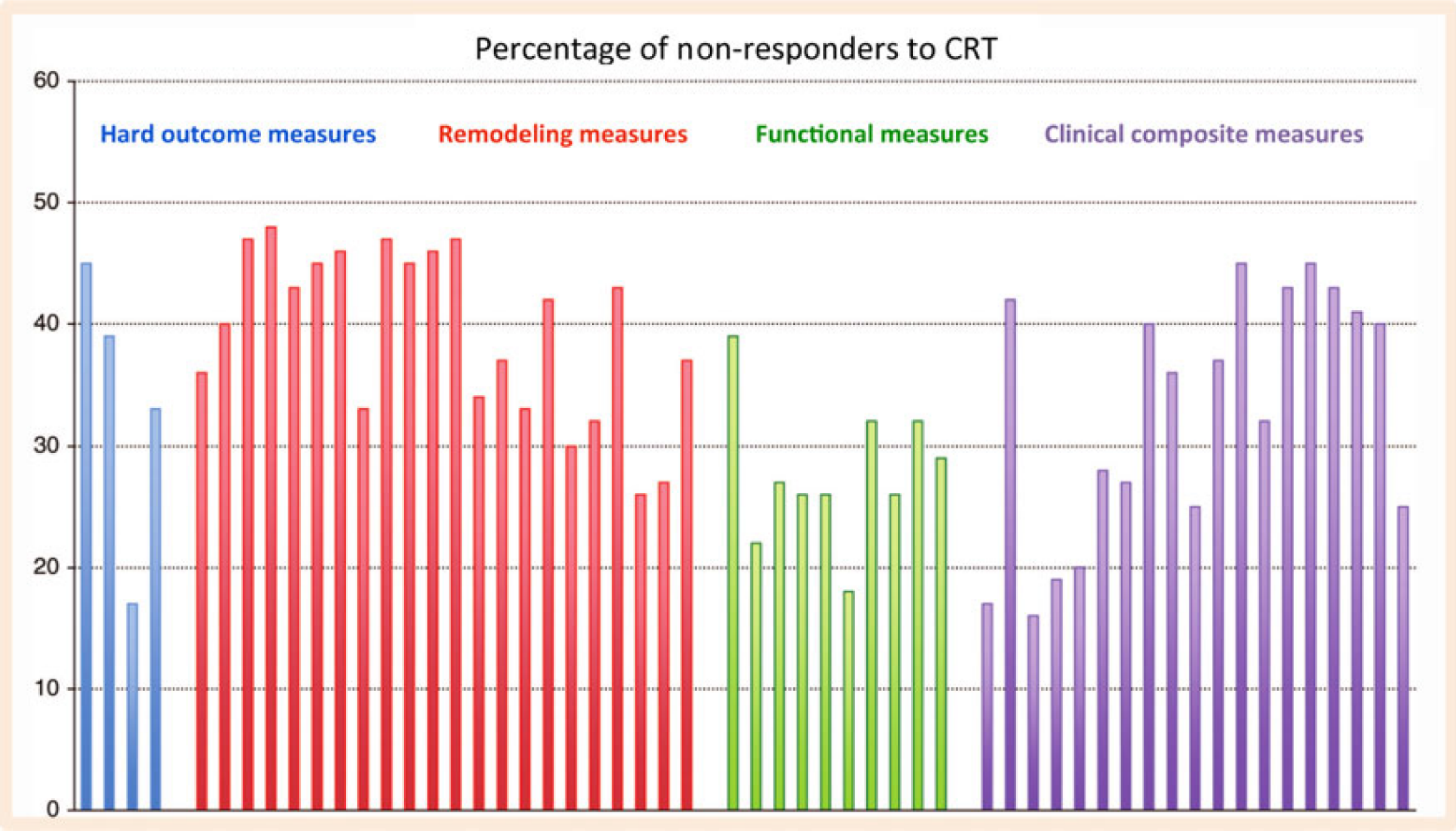
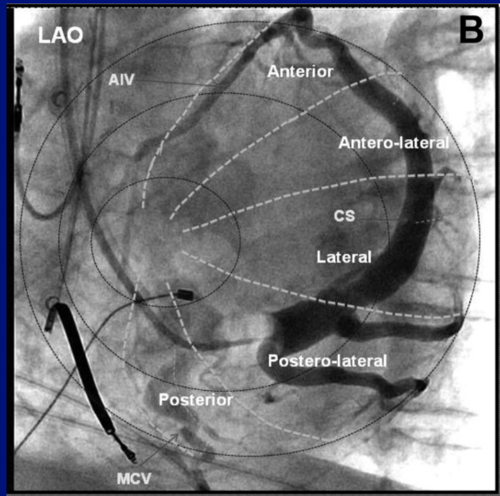
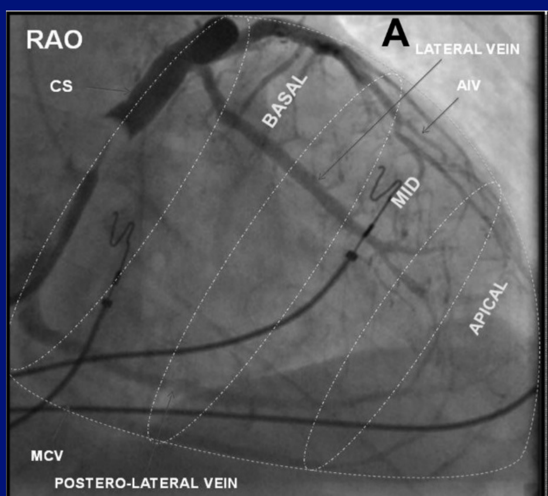
Non-Responders to CRT

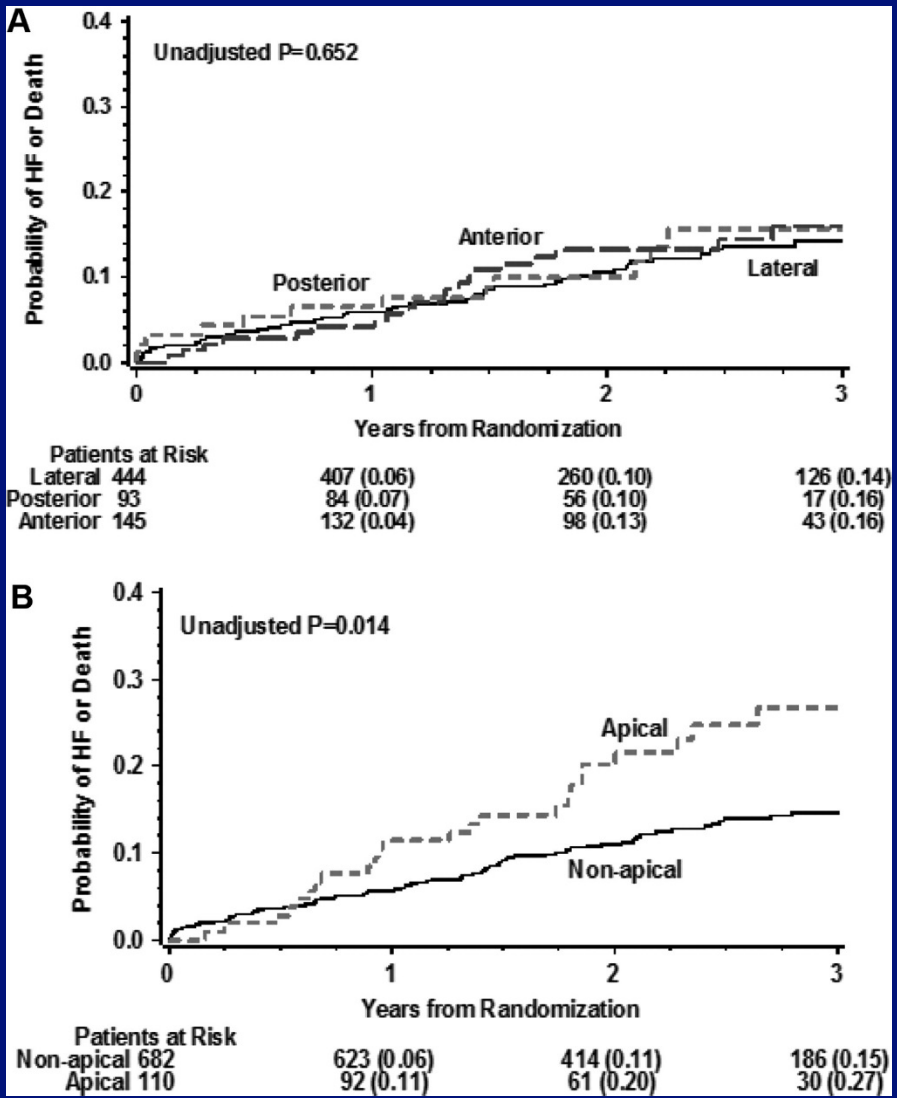


Daubert et al. European Heart J 2016 doi:10.1093/eurheartj/ehw270

LV Lead Position and Clinical Outcome in the MADIT-CRT Trial



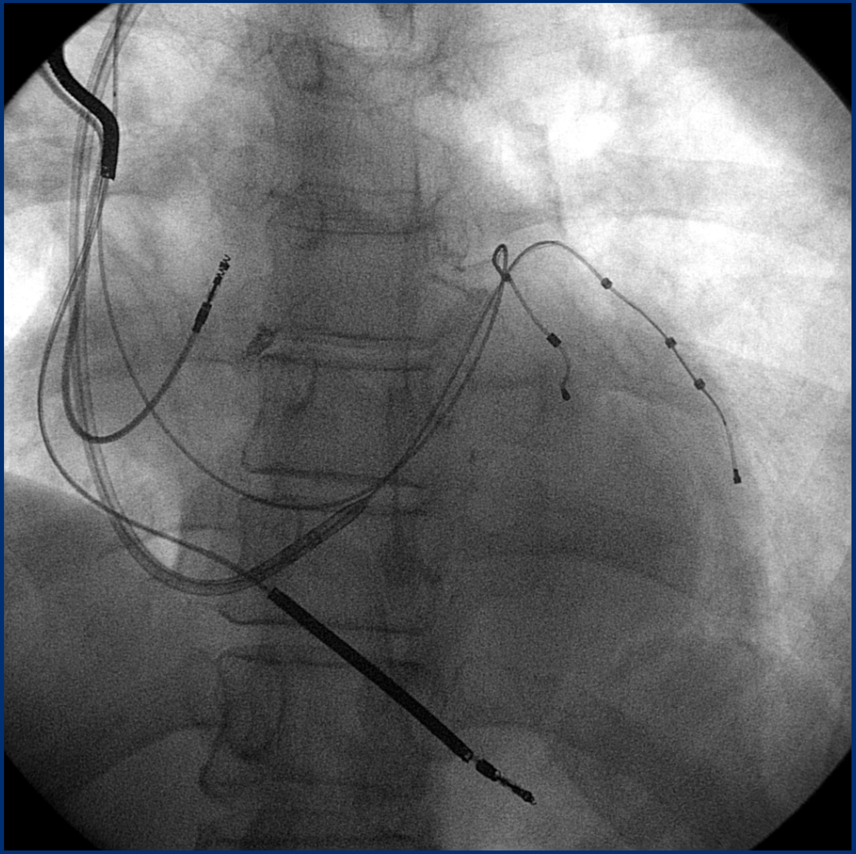




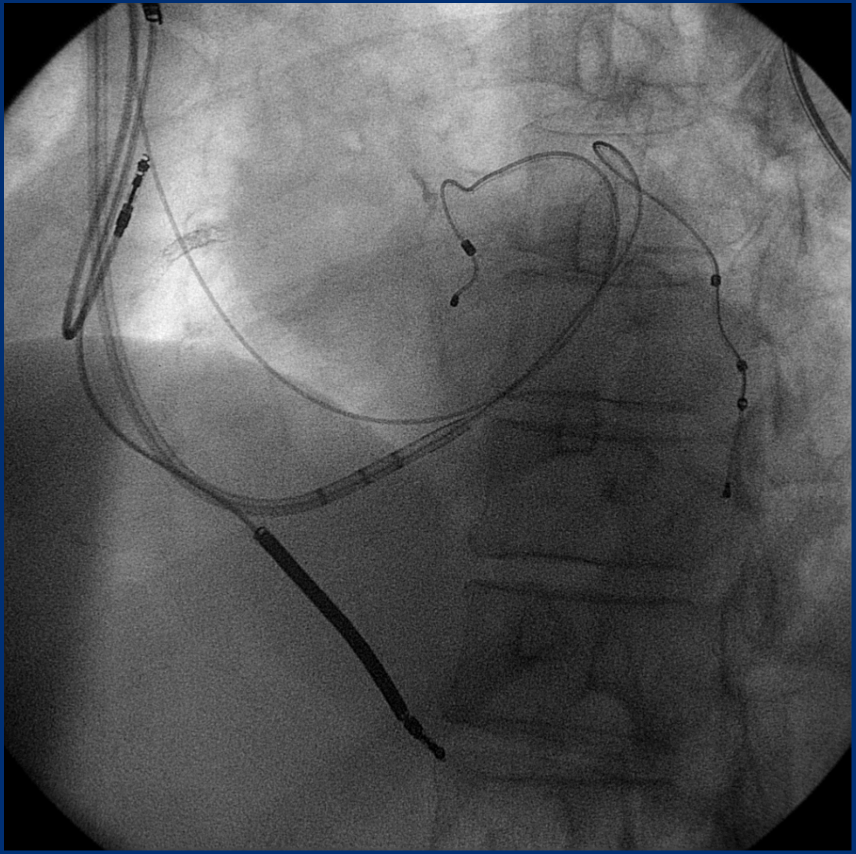
Singh, J. P. et al. Circulation 2011;123:1159-1166

Leads in Both Anterior Interventricular and Anterolateral Vein

PA

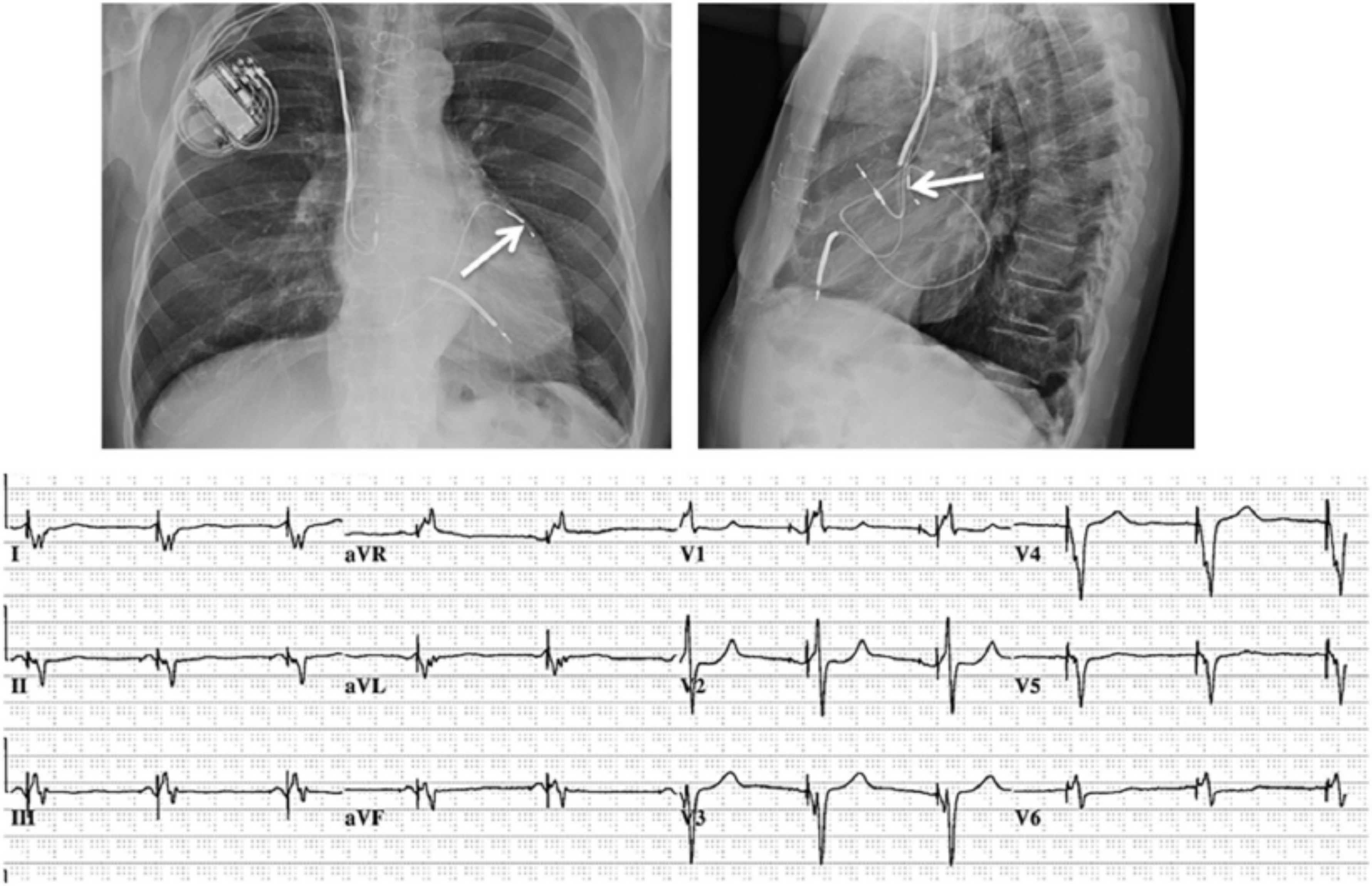


LAO



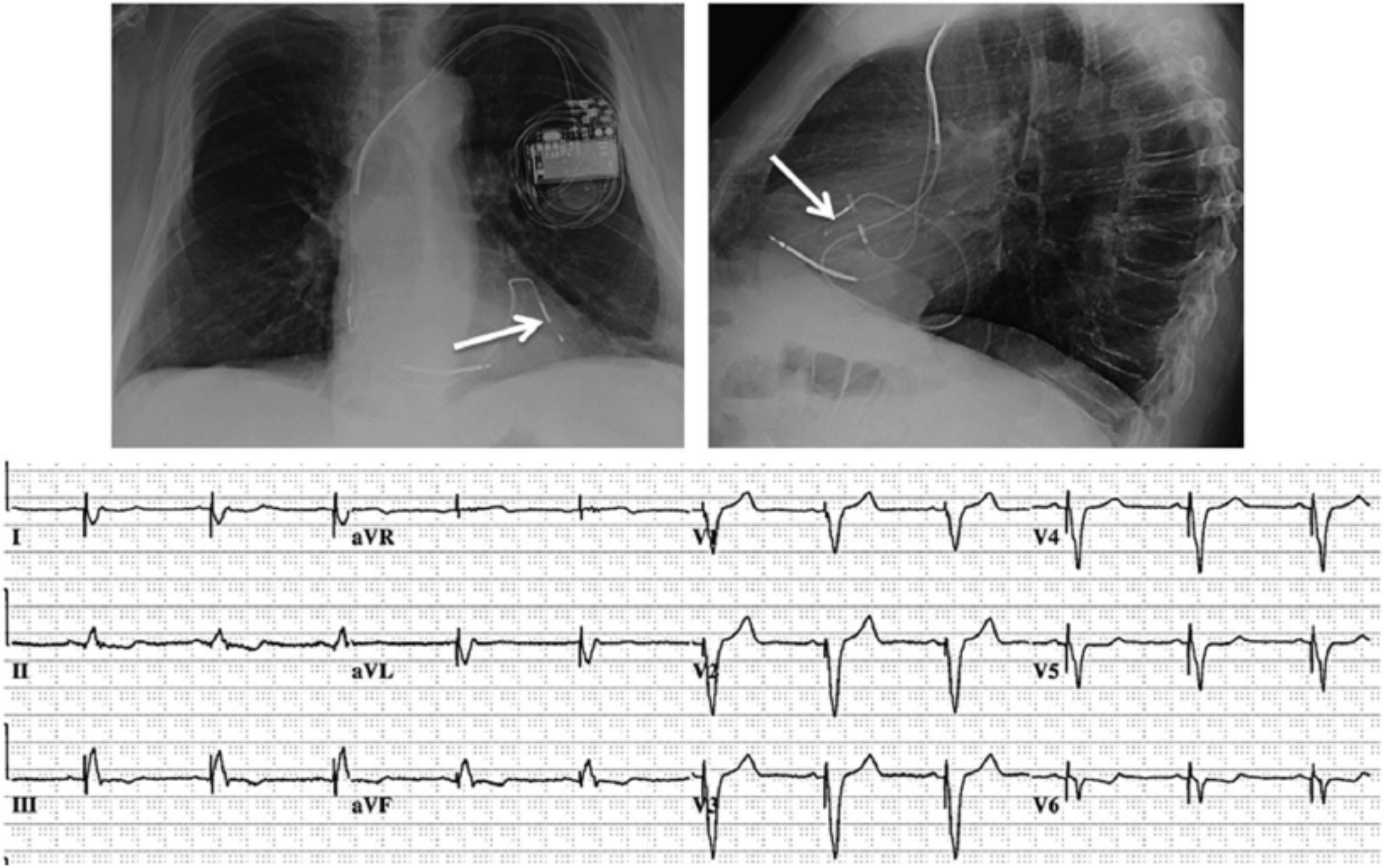
E

Anterolateral Coronary Sinus Branch



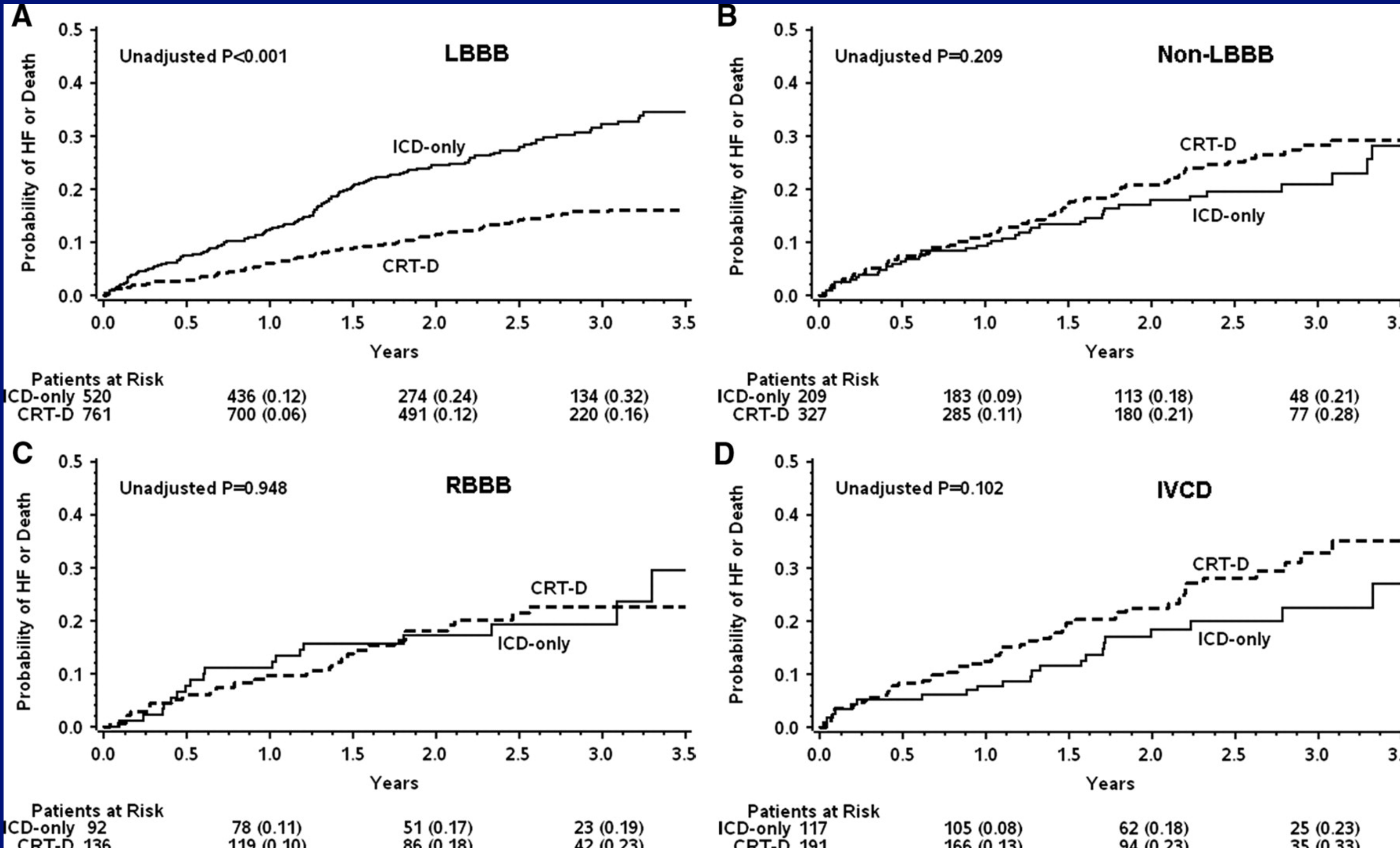
Madhavan et al. J Am Coll Cardiol 2017;69:211–35

F Anterior Interventricular Vein



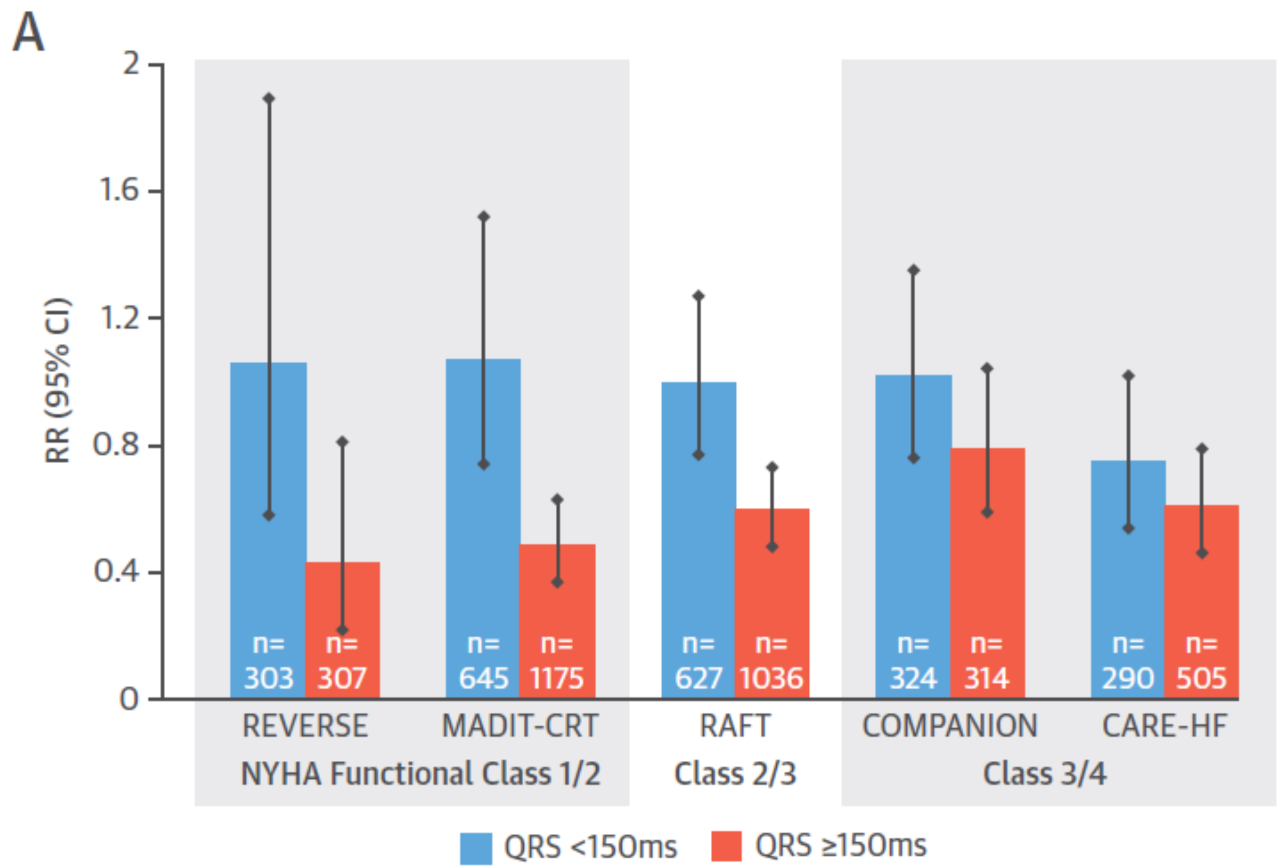
Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Effectiveness of Cardiac Resynchronization Therapy by QRS Morphology in the Multicenter Automatic Defibrillator Implantation Trial–Cardiac Resynchronization Therapy (MADIT-CRT)



Zareba, W. et al. Circulation 2011;123:1061-1072

FIGURE 4 Effect of CRT in Randomized Clinical Trials and Indications for CRT for Patients in Sinus Rhythm

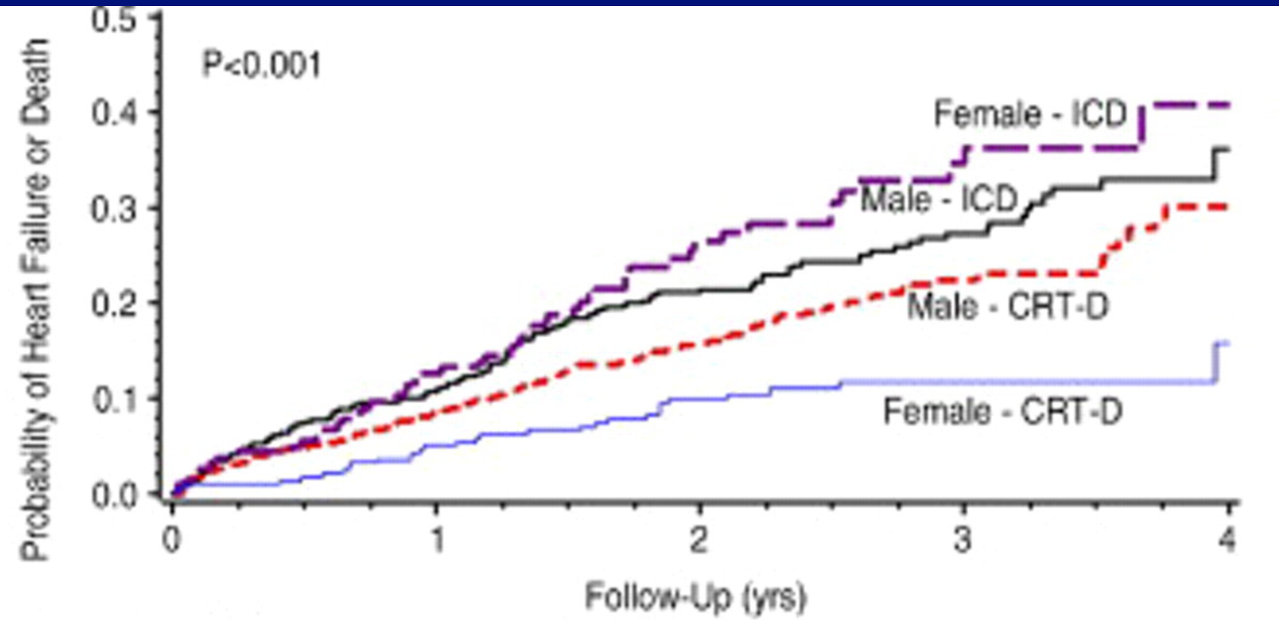


Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Cardiac Resynchronization Therapy Is More Effective in Women Than in Men

The MADIT-CRT

Kaplan-Meier Estimates of Cumulative Probability of Heart Failure or Death Stratified by Sex and ICD or CRT-D Therapy



Patients at Risk

Male - ICD 553	472 (0.11)	293 (0.21)	137 (0.27)	34 (0.36)
Male - CRT-D 814	732 (0.09)	478 (0.16)	206 (0.22)	40 (0.30)
Female - ICD 178	148 (0.13)	84 (0.27)	37 (0.36)	10 (0.41)
Female - CRT-D 275	253 (0.05)	175 (0.10)	72 (0.12)	18 (0.16)

Arshad, A. et al. J Am Coll Cardiol 2011;57:813-820

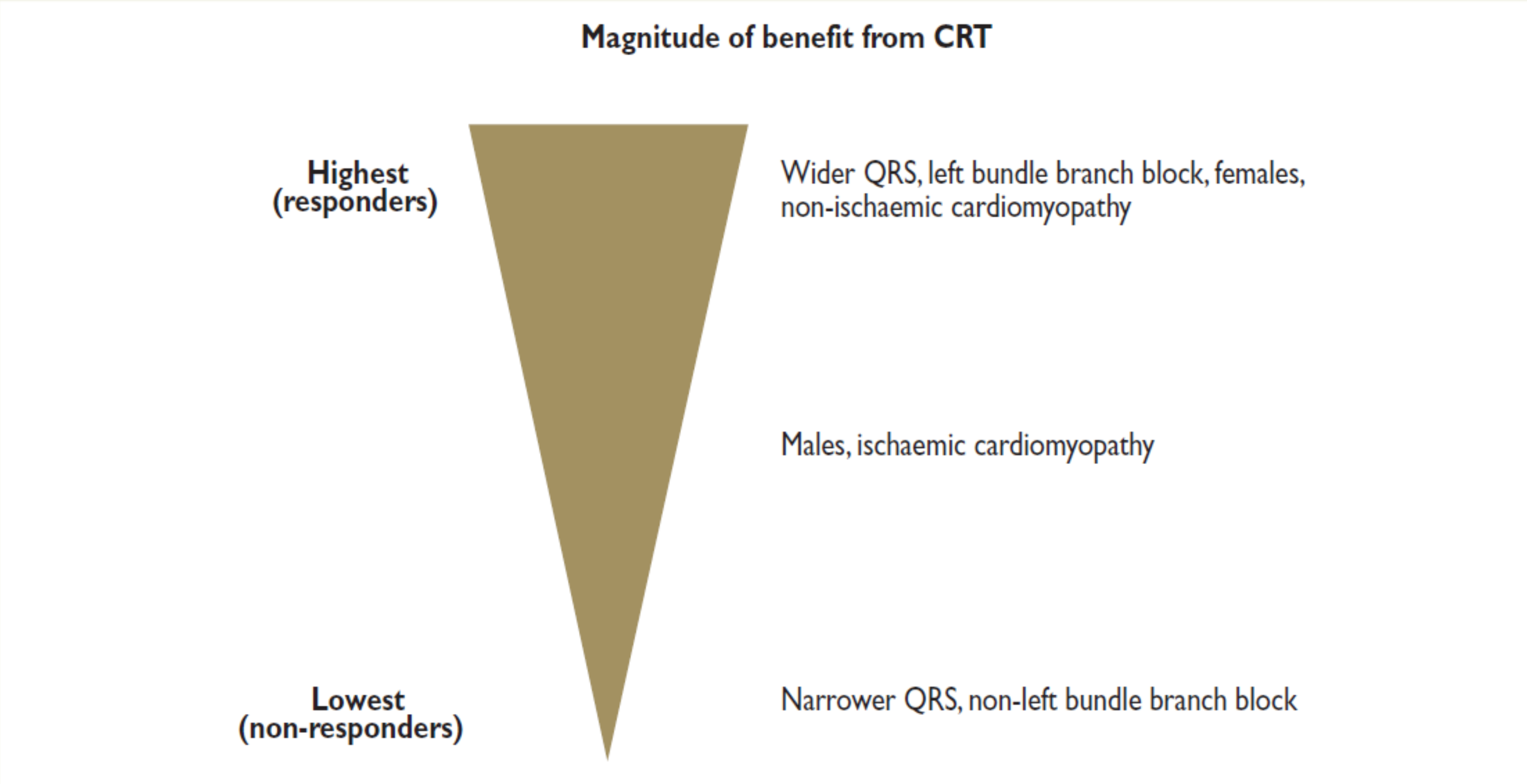


Figure 8 Clinical factors influencing the likelihood to respond to CRT.

2013 ESC guidelines on cardiac pacing and cardiac resynchronization therapy.
European Heart Journal (2013) 34, 2281–2329

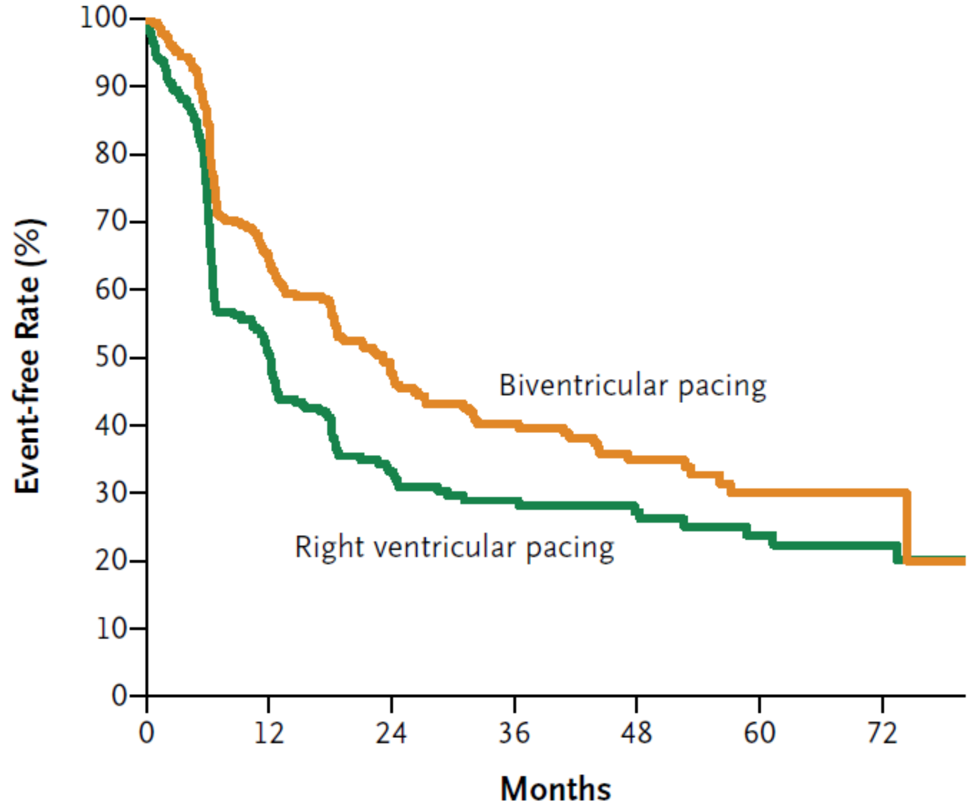
Good Response to CRT

- Good patient selection
  - Sinus rhythm versus AF
    - Although AF almost as good if AVN ablated
  - LBBB versus nonspecific IVCD/RBBB
  - QRS > 150
  - NICM versus ICM
  - Absence of comorbidities (e.g. renal insufficiency)
- Good LV lead positioning
  - Short-axis, long-axis location
  - Remote from scars
  - Target site of latest activation

Indications for Biventricular Pacing
Special Situations

- "Iatrogenic LBBB": Patients with preexisting RV pacemaker who have class III-IV CHF, EF <35%, and pace the ventricle most of the time.
- Patients with predominantly atrial fibrillation (not included in the large trials), IVCD, class III-IV CHF, and EF <35%
  - Ventricular rate must be slowed (drugs and/or AV ablation) to allow 100% pacing.
- Patients with rapid atrial fibrillation and EF <35% who undergo AV junctional ablation and pacemaker implantation.

Biventricular Pacing for AV Block and Systolic Dysfunction (BLOCK HF)



No. at Risk							
Biventricular pacing	349	161	87	62	38	17	3
Right ventricular pacing	342	126	59	39	28	18	10

The primary outcome was the time to a first event of death from any cause, an urgent care visit for heart failure that required intravenous therapy, or an increase in the left ventricular end-systolic volume index of 15% or more

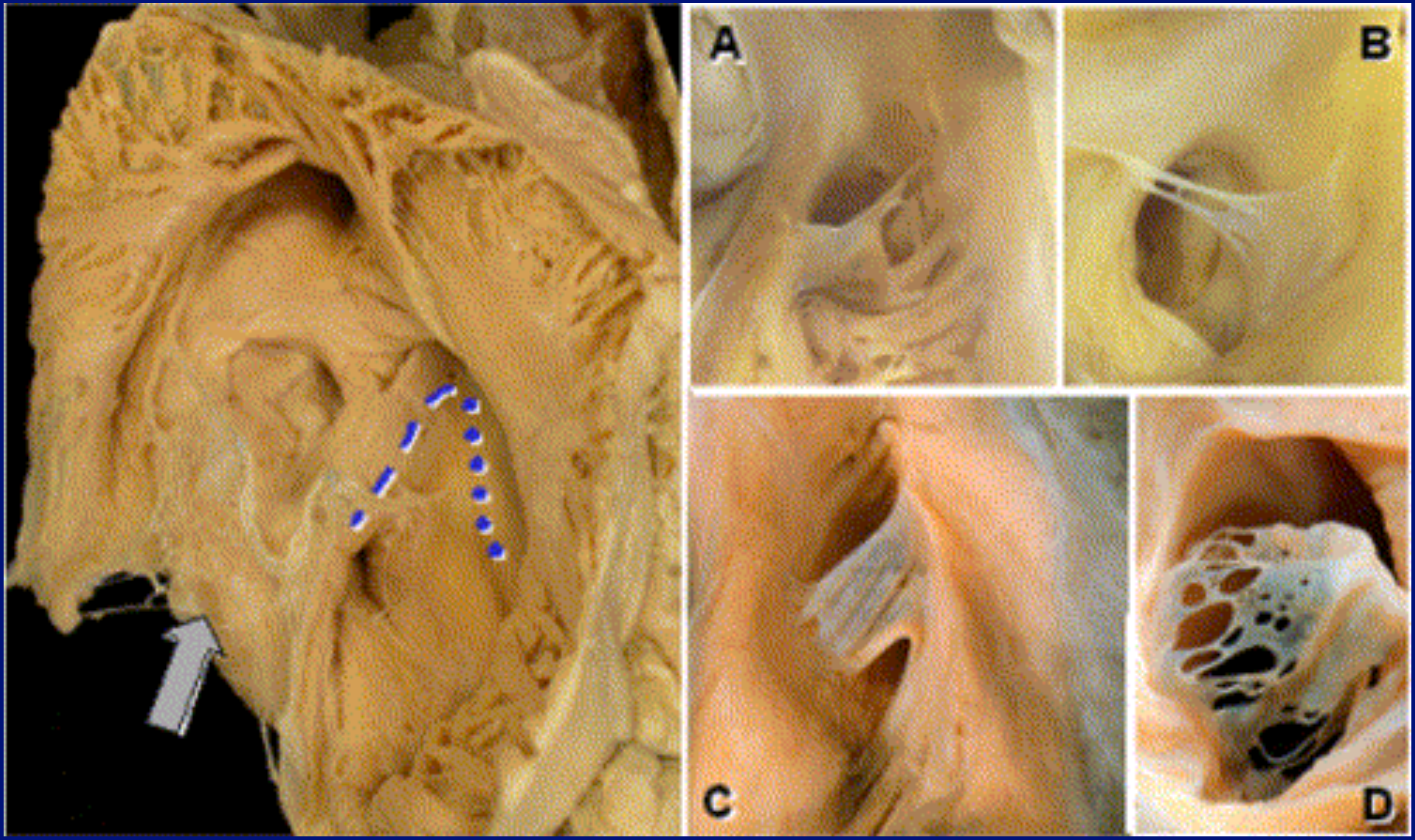
Curtis et al. NEJM 2013;368:1585

COMPANION Study

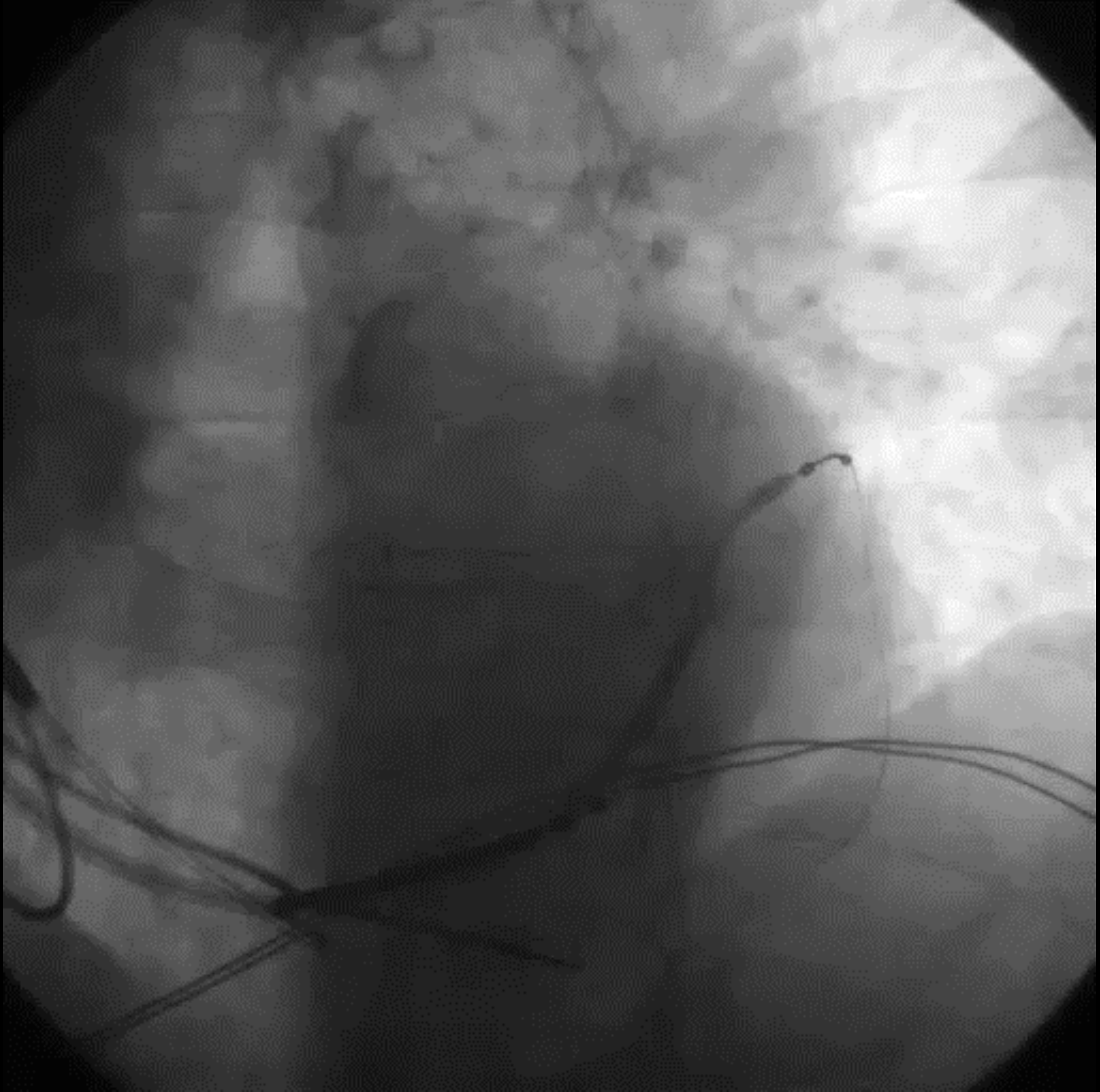
Bristow et al, NEJM 2004;350:2140

- CRT implant successful in 87-91% pts
- Death from procedure in 0.5-0.8% pts
- Moderate or severe adverse events related to implant in 8-10% pts
  - Coronary venous dissection: 0.3-0.5%
  - Coronary venous perforation: 0.8-1.1%
  - Coronary venous tamponade: 0.3-0.5%

Coronary Sinus Anatomy



Ho et al, Heart Rhythm 2004;1:107-112



VENTAK CHF/CONTAK CD Biventricular Pacing Study

Table 1. Causes and Frequencies of Coronary Venous Lead Implantation Failure

Cause	n (%)
Inability to cannulate the coronary sinus	29 (6%)
Inability to obtain a stable pacing site	24 (5%)
Inability to obtain adequate pacing thresholds	6 (1%)
Coronary sinus dissection/perforation	5 (1%)
Diaphragmatic stimulation that could not be corrected	1 (0.2%)
Inability to place a right atrial pacing lead	1 (0.2%)
Transient atrioventricular block caused by guide catheter	1 (0.2%)
Vascular trauma during attempt at venous access	1 (0.2%)
No reason reported	1 (0.2%)
Total	69/512 (13%)

Knight et al. JACC 2004;44:72

VENTAK CHF/CONTAK CD Biventricular Pacing Study

Table 3. Causes and Frequencies of Temporary and Permanent Loss of CRT During Follow-Up in 443 Patients Who Underwent Successful Implantation of a Defibrillator With CRT

Cause	CRT Interrupted n (%)	CRT Restored n (%)	CRT Permanently Lost n (%)
Atrial tachyarrhythmia	81 (18)	79 (18)	2 (0.5)
Loss of left ventricular capture	44 (10)	39 (9)	5 (1)
Extracardiac stimulation	11 (2)	6 (1)	5 (1)
Loss of right ventricular capture	9 (2)	9 (2)	0
Infection/pericarditis	5 (1)	2 (0.5)	3 (1)
Patient intolerance	5 (1)	1 (0.2)	4 (1)
Loss of right atrial sensing	5 (1)	5 (1)	0
Ventricular oversensing	1 (0.2)	0	1 (0.2)
Total	161 (36)	141 (32)	20 (5)

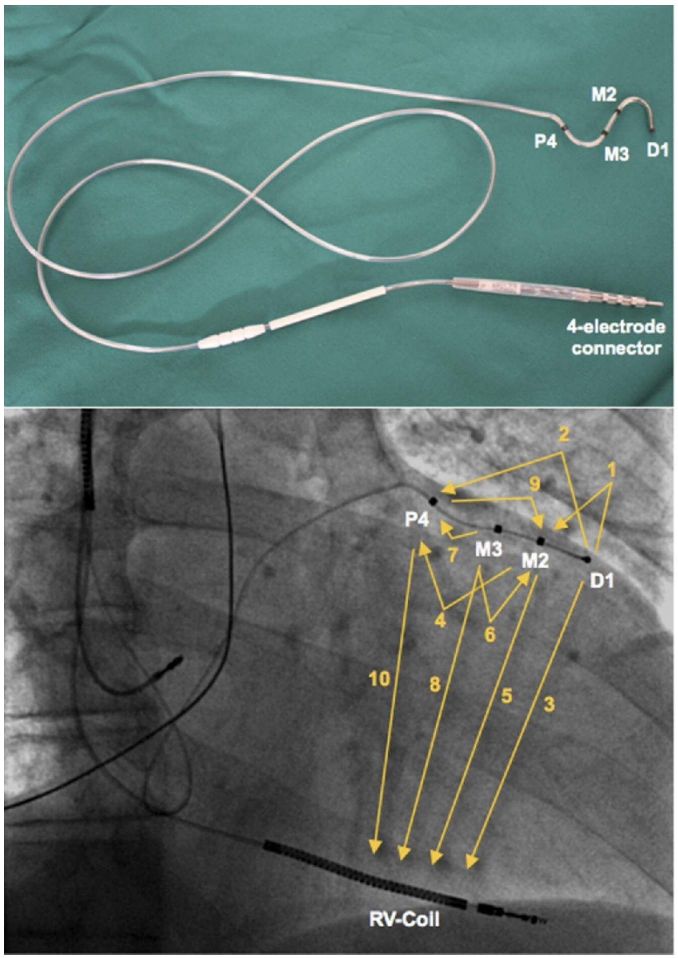
Knight et al. JACC 2004;44:72

Cardiac Resynchronization

Pacing Variables

- Site of pacing
- AV interval
- RV-LV stimulation delay

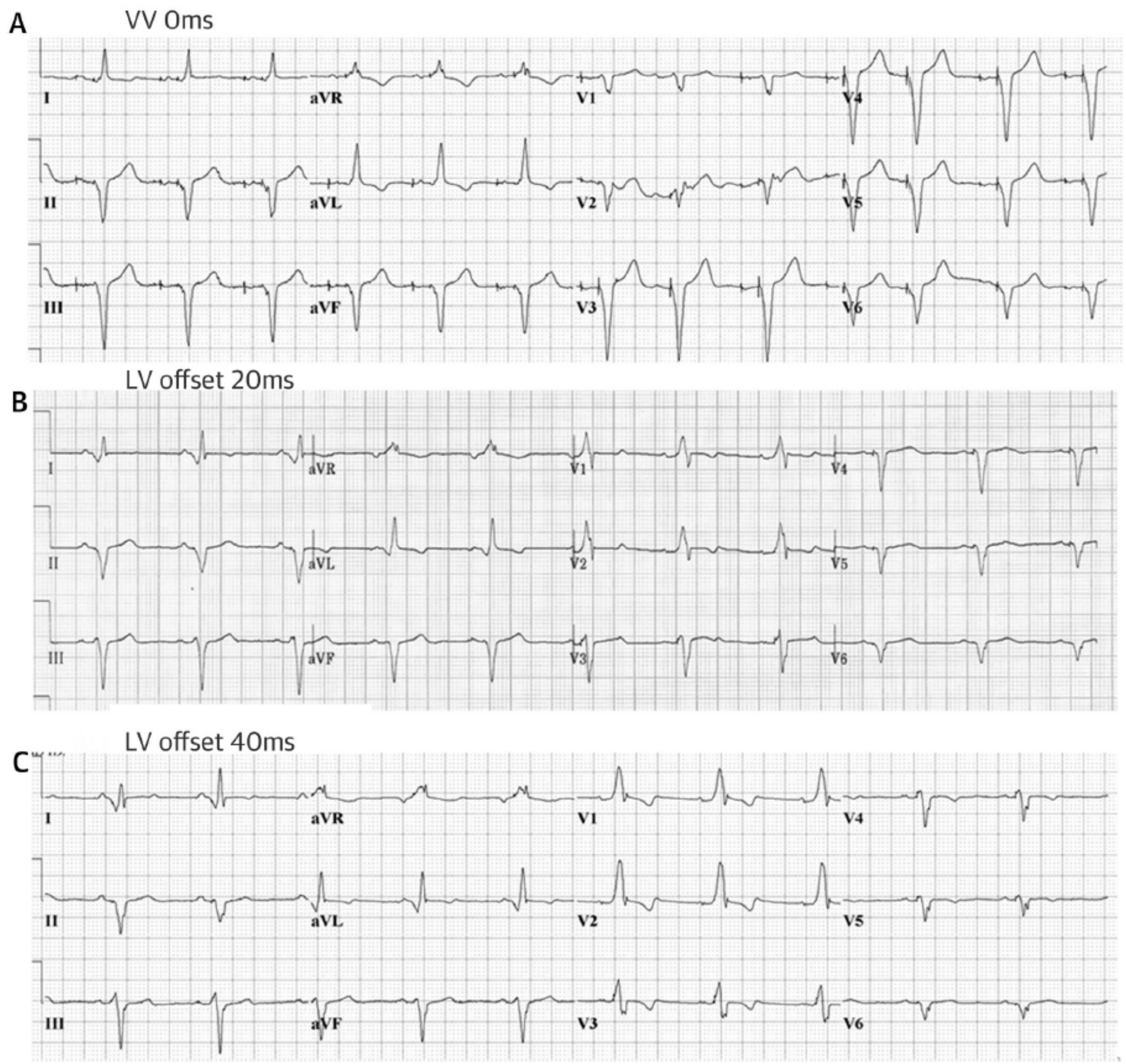
Left ventricular pacing with a new quadripolar transvenous lead for CRT



VECTOR	DESCRIPTION	CATHODE	ANODE
1	Distal-Tip to Mid-2	D1	M2
2	Distal-Tip to Proximal-4	D1	P4
3	Distal-Tip to RV-Coil	D1	RV-Coil
4	Mid-2 to Proximal-4	M2	P4
5	Mid-2 to RV-Coil	M2	RV-Coil
6	Mid-3 to Mid-2	M3	M2
7	Mid-3 to Proximal-4	M3	P4
8	Mid-3 to RV-Coil	M3	RV-Coil
9	Proximal-4 to Mid-2	P4	M2
10	Proximal-4 to RV-Coil	P4	RV-Coil

Forleo et al. Heart Rhythm 2011;8:31

FIGURE 6 Optimization of the VV Interval Using Electrocardiography



Madhavan et al. J Am Coll Cardiol 2017;69:211–35

CRT—Initial Evaluation of Nonresponders

- Confirm LV lead capture
- Optimize percent V pacing
  - Shorten AV delay
  - Optimize AF rate or rhythm control
    - Consider His ablation
  - Control ventricular ectopy
  - Pacing algorithms to force ventricular pacing
- Optimize AV, VV intervals

Patients in Whom CRT Should be Delayed

- Flash pulmonary edema or marked exertional intolerance
  - Investigate for ischemic and/or valvular dysfunction
- Anasarca; ↑↑ filling pressures
  - diurese
- Not receiving optimal medical therapy
  - ACE or ARB, beta blocker

Patients Who May Not Be Candidates For CRT

- Dependence on IV inotropes
- Progressive renal dysfunction
- Severe cachexia
- Consideration for mechanical circulatory assist devices

Indications for CRT

Guidelines from the AHA/ACC

LVEF ≤35%, QRS Duration ≥120 ms and Sinus Rhythm

QRS morphology	QRS duration (ms)	NYHA functional class	Level of recommendation
LBBB	≥150	II, III, ambulatory IV	Class I
	120-149	II, III, ambulatory IV	Class IIa
	≥150	I + LVEF ≤30% + ischemic heart disease	Class IIb
Non-LBBB	≥150	III, ambulatory IV	Class IIa
	120-149	III, ambulatory IV	Class IIb
	≥150	II	Class IIb
	120-149	I, II	Class III (no CRT)
Significant (>40%) ventricular pacing	Any QRS	I, II, III, ambulatory IV	Class IIa

Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Key Points---CRT

- The presence of left bundle branch block (LBBB) pattern remains the most powerful predictor of CRT response.
- The wider the QRS complex, the greater the likelihood of response.

Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:189–210

Key Points---CRT

- Women are more likely to benefit from CRT than men, particularly when the QRS duration is <150 ms.
- When patients with depressed ventricular function and a pacemaker manifest an LBBB that is caused by frequent right ventricular (RV) pacing, upgrading to a CRT system often improves ventricular function.

Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Key Points---CRT

- There is strong evidence to support CRT use in patients with NYHA class II heart failure (HF) and higher.

Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Key Points---CRT

- Biventricular pacing can reasonably be considered in patients who are anticipated to require a high percentage of ventricular pacing and have ejection fraction ≤50% with mild HF symptoms.

Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Key Points---CRT

- Three multicenter trials failed to show substantial improvement in CRT response with dyssynchrony assessment by echocardiography, and the EchoCRT study found increased mortality in patients with a QRS complex <130 ms and echocardiographic dyssynchrony.

Thomas C. Crawford, Jan 12, 2017 CardioSource, adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

Key Points---CRT

- In terms of coronary sinus lead location, posterior and lateral positions are generally preferred, and apical positions should be avoided.
- Maximizing the distance between the RV and LV electrodes is also associated with better CRT response.
- The site of latest electrical local left ventricular (LV) activation also constitutes a preferred pacing site.

Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

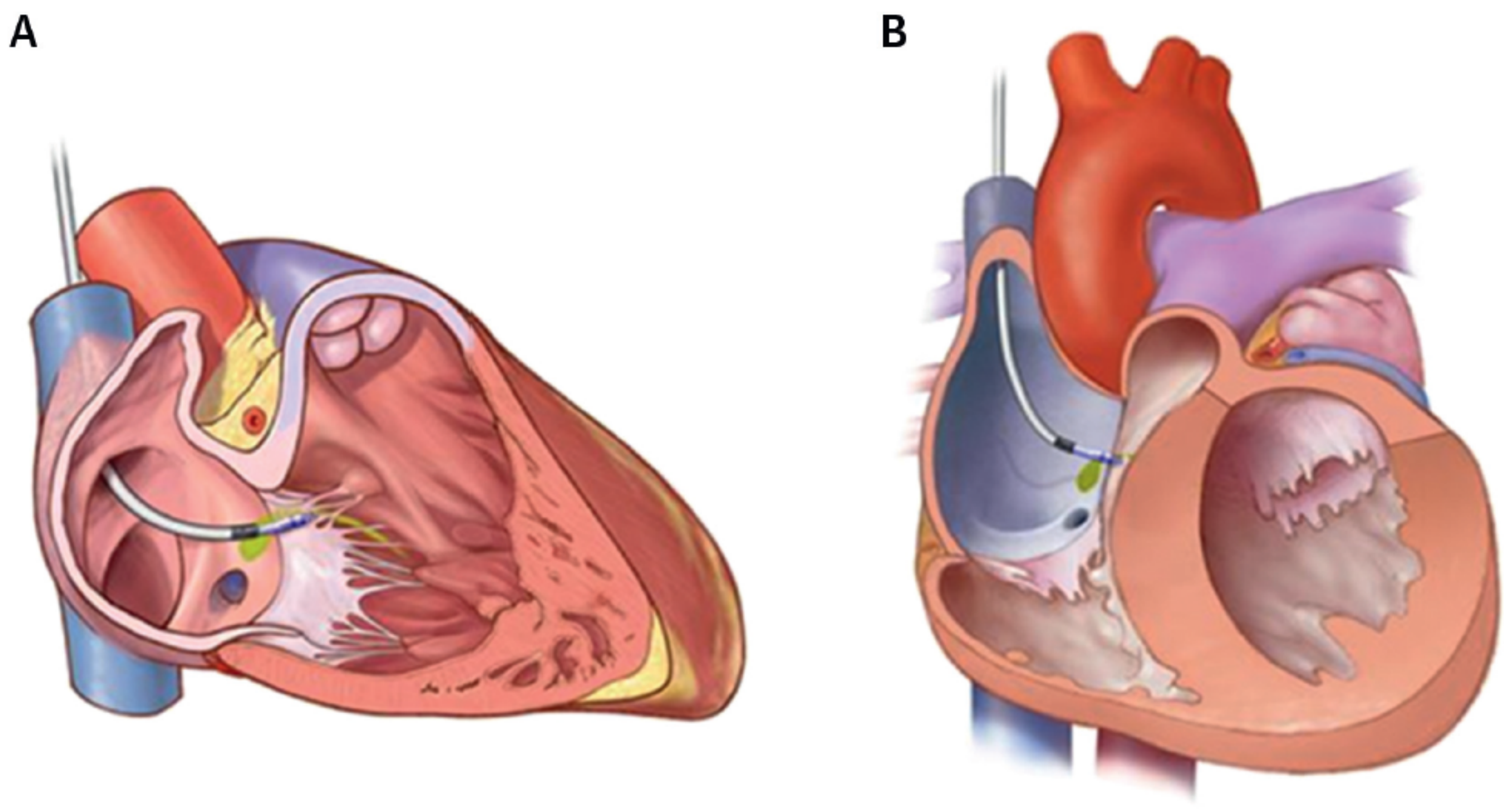
Key Points---CRT

- Frequent premature ventricular contractions (PVCs) interfere with CRT and may independently worsen HF due to dyssynchrony.
- Treatment with beta-blockers, membrane-active antiarrhythmic drugs, and catheter ablation of PVCs may improve CRT response.
- In patients with permanent atrial fibrillation (AF) who need CRT, a reasonable approach is to start with pharmacological rate control and rapidly escalate to atrioventricular (AV) node ablation if >99% biventricular pacing is not achieved with medications alone.

Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

His Bundle Pacing

FIGURE 8 His Bundle Pacing

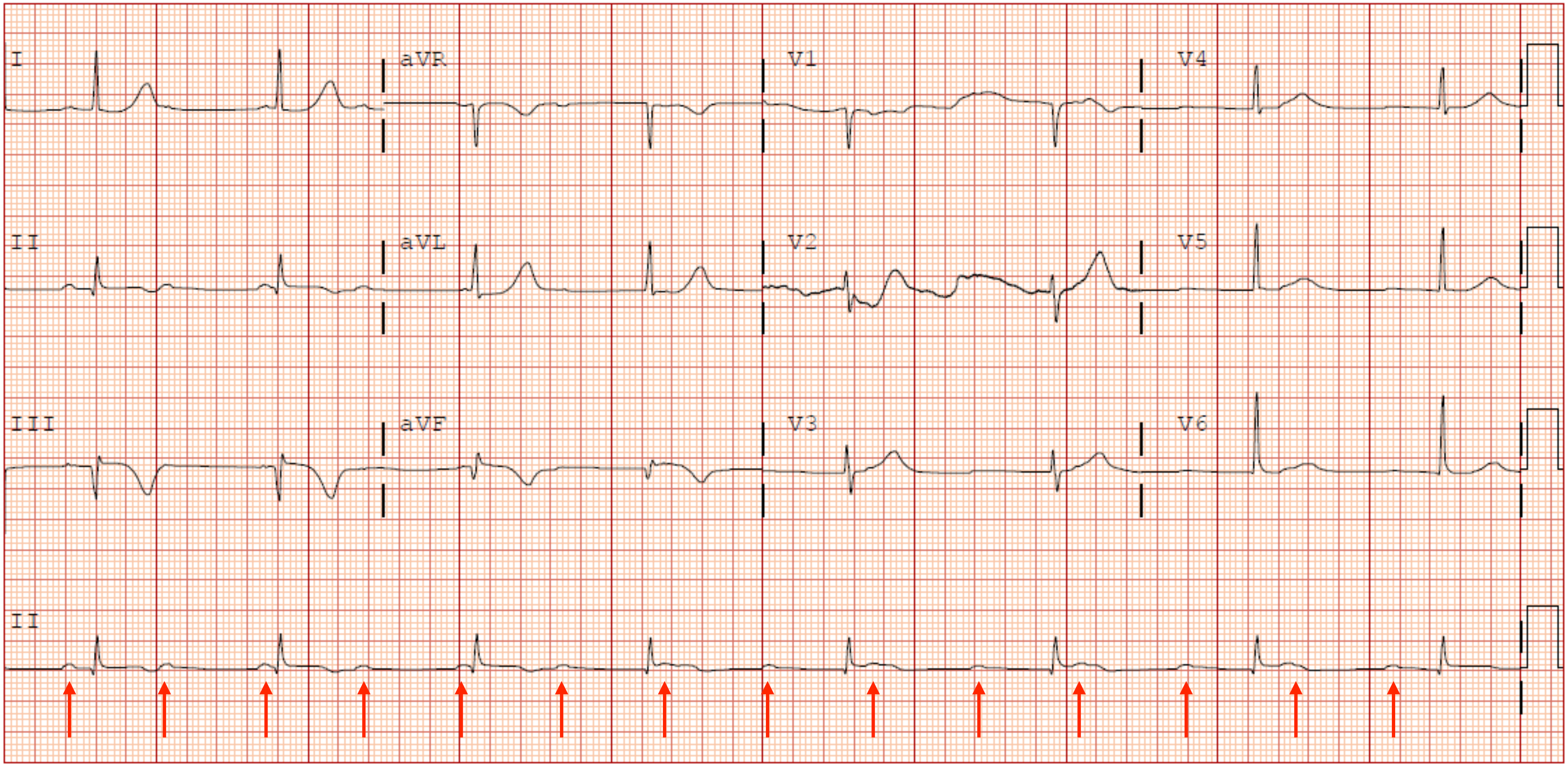


Madhavan et al. J Am Coll Cardiol 2017;69:211–35

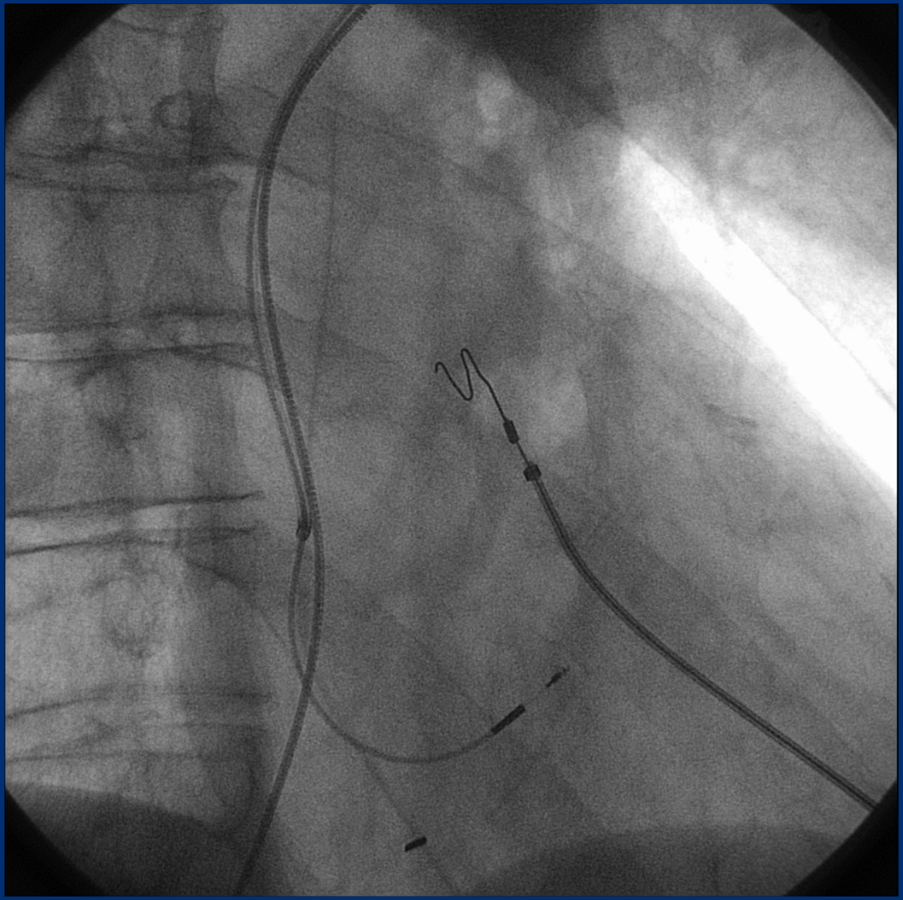
Key Points---Para-His Pacing

- His-bundle capture enables rapid activation of the ventricles by engaging the Purkinje network and results in a narrow QRS complex.
- This can be achieved with a small-caliber pacing lead delivered through specially designed sheaths.

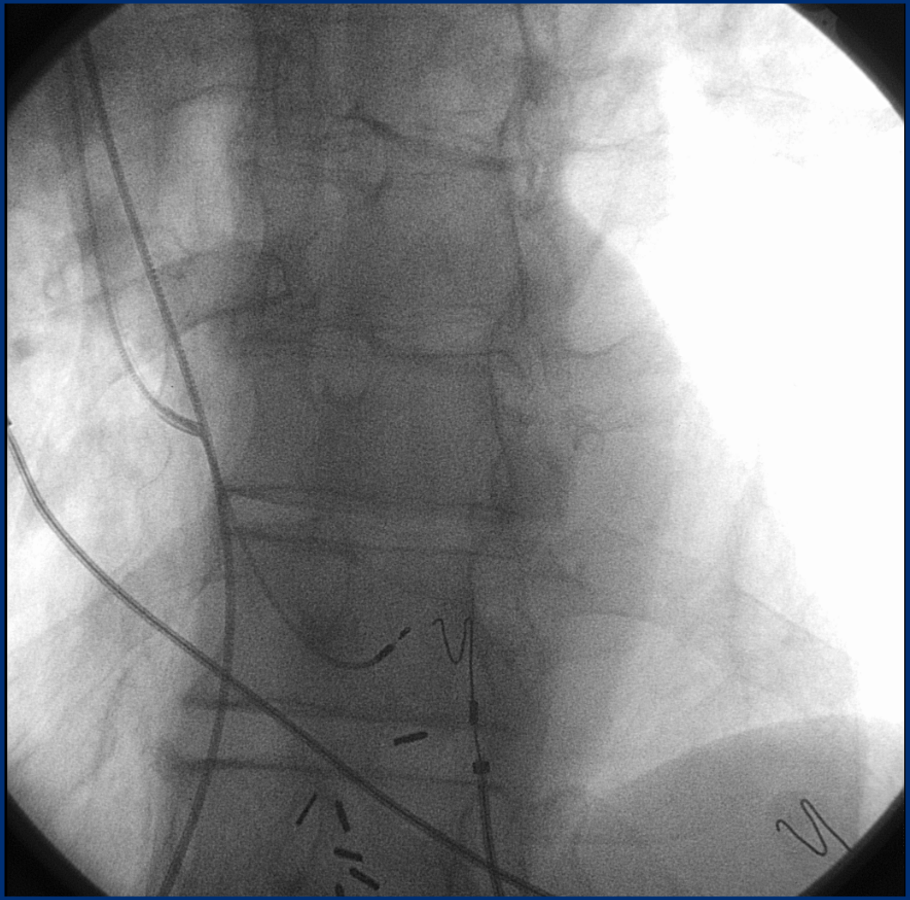
Thomas C. Crawford, Jan 12, 2017 CardioSource,
adapted from Madhavan et al. J Am Coll Cardiol 2017;69:211–35

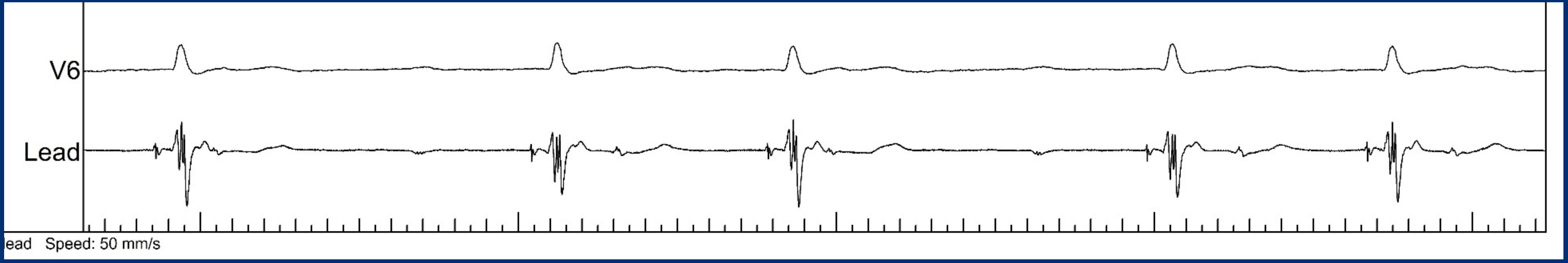

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

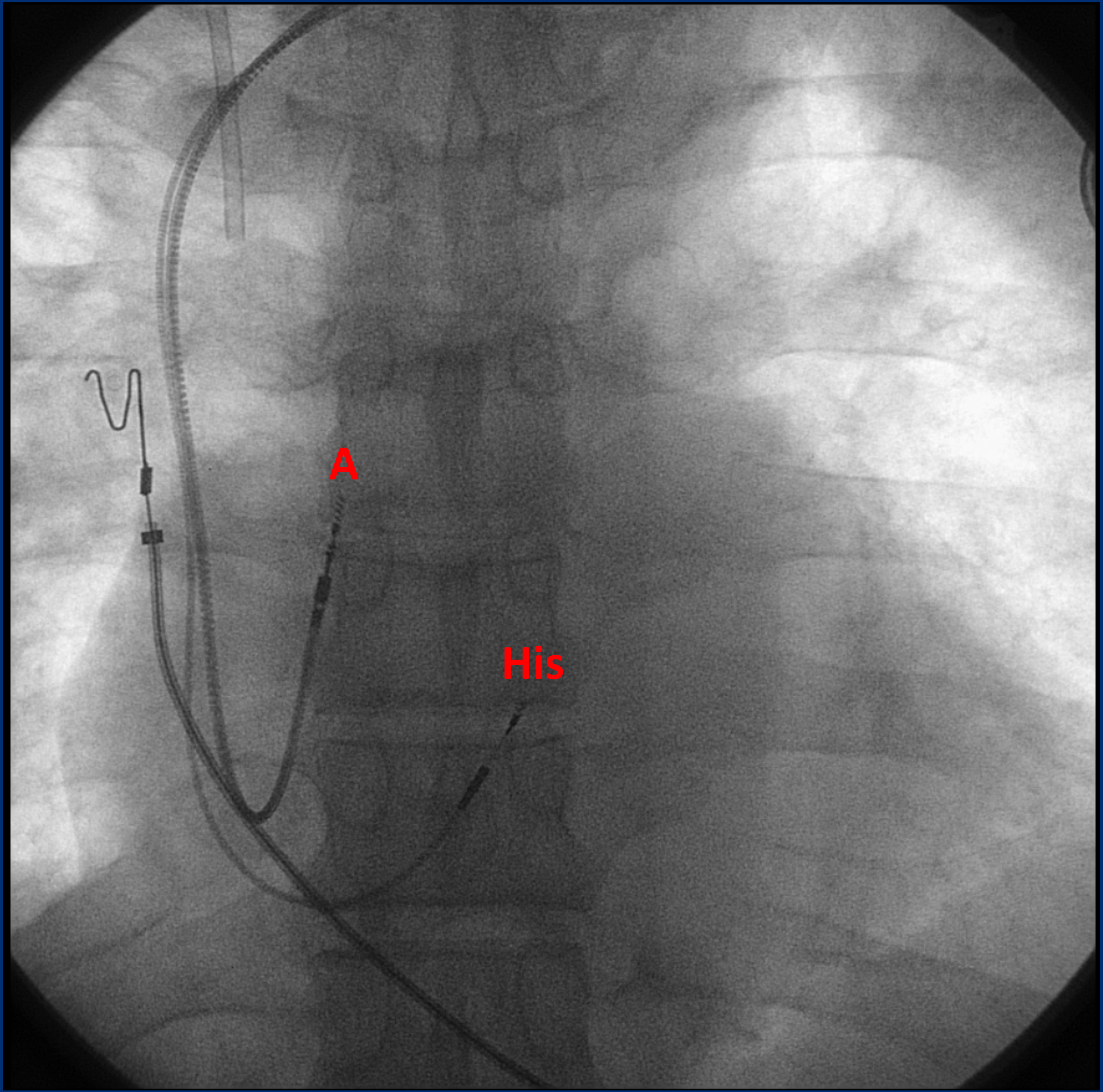
RAO



LAO



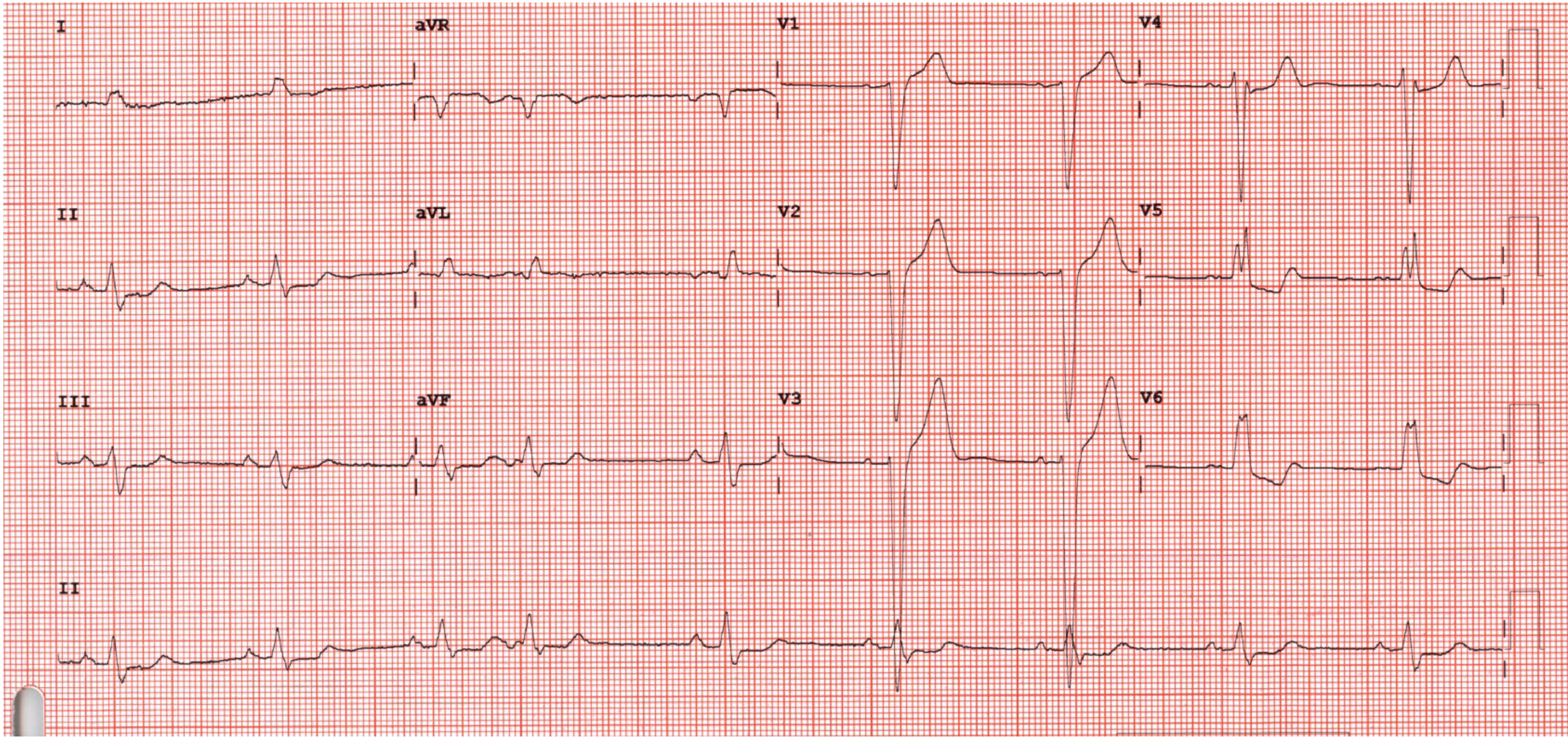


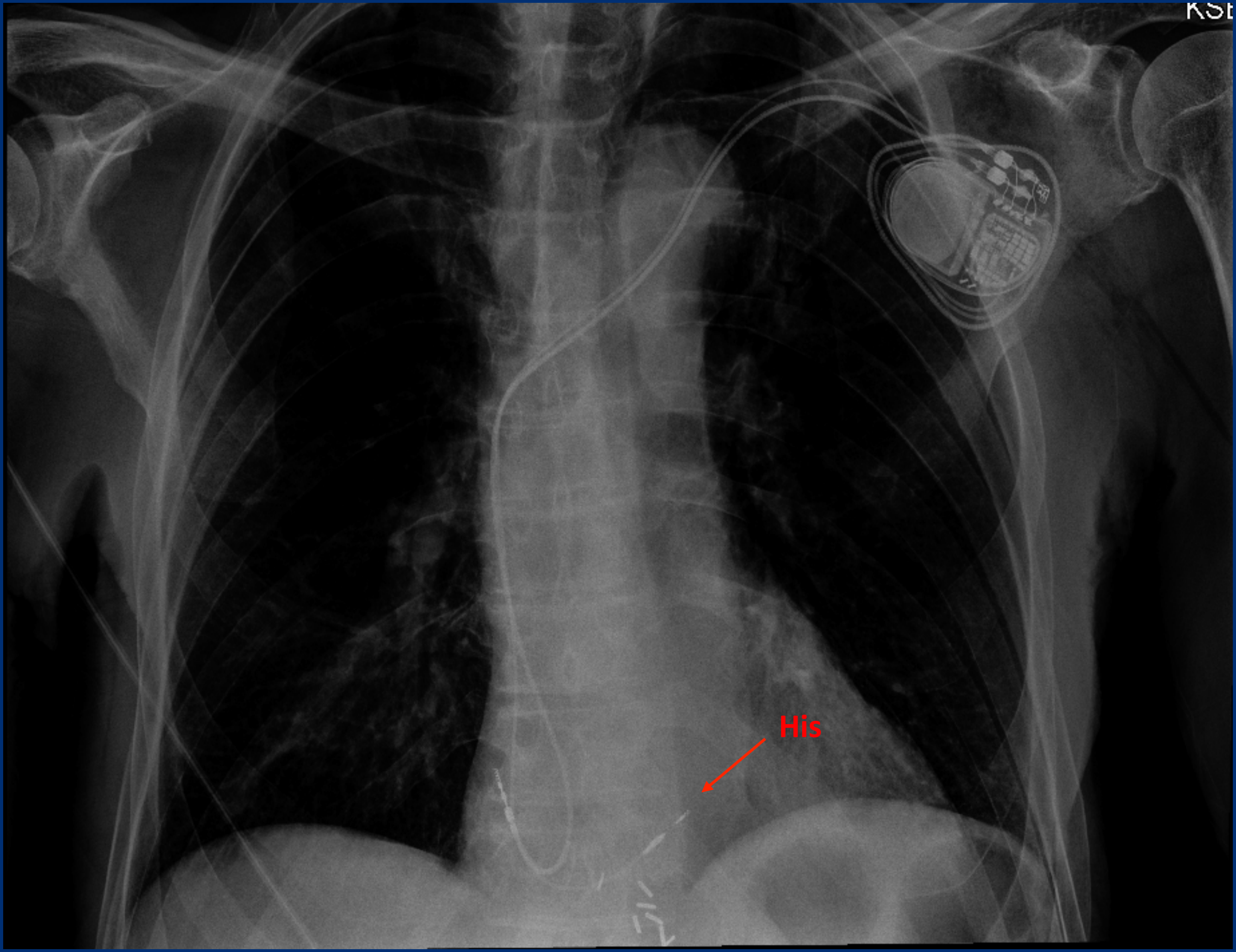

A
His

Potential Uses of His Bundle Pacing

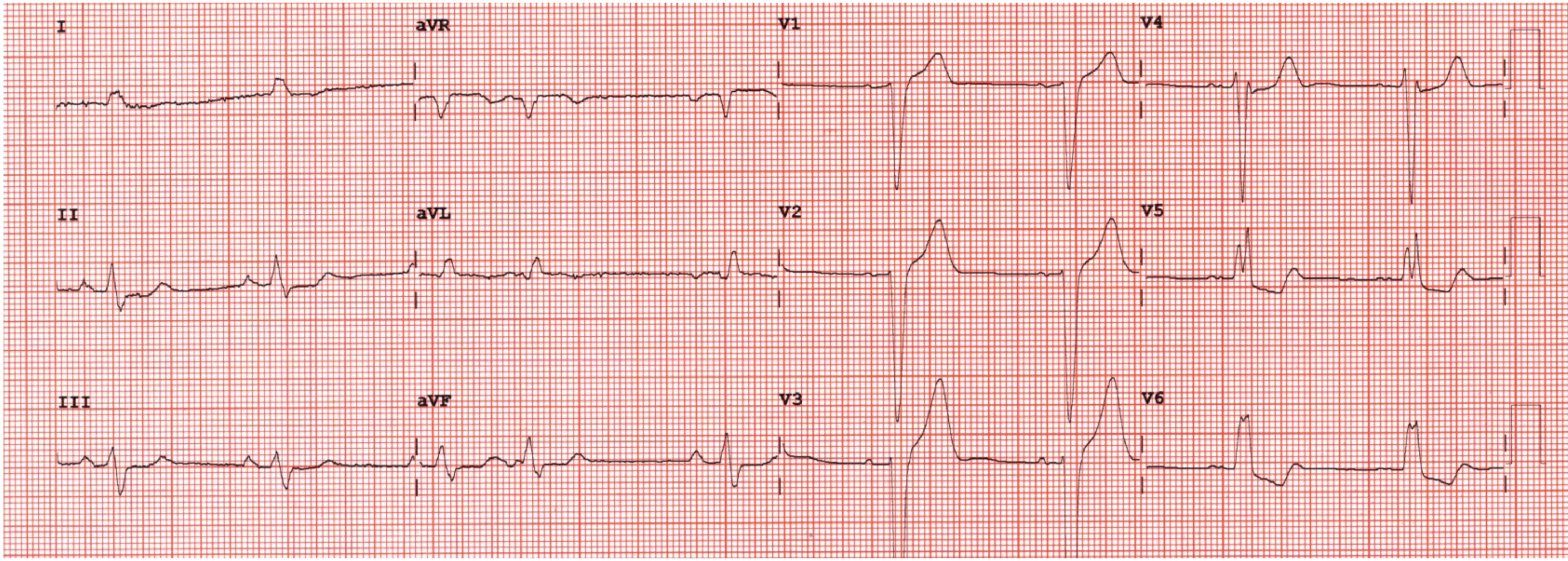
- Pacing the ventricle via the intrinsic conduction system preserves ventricular synchrony and can prevent the deleterious effects of chronic RV pacing.
- In some patients with bundle branch block, His bundle pacing can narrow the QRS and restore ventricular synchrony

79 y/o male with symptomatic sinus bradycardia, LBBB, LVEF 25-30%.

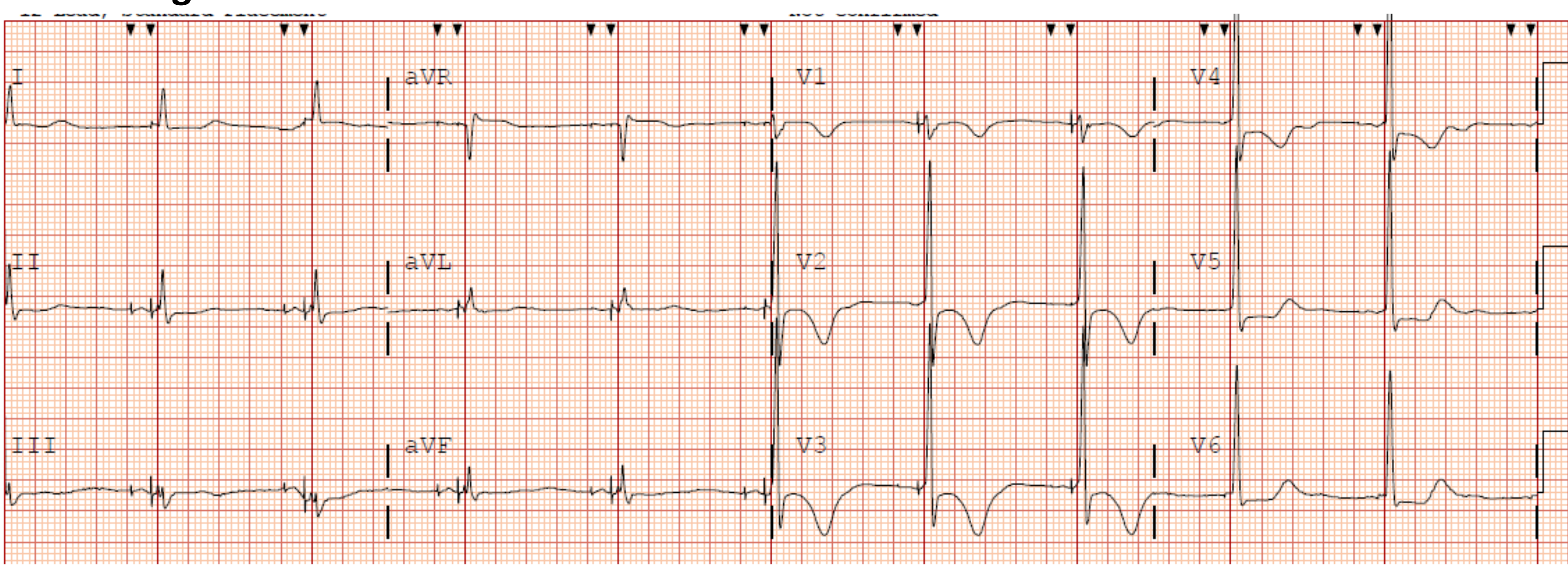



His

Before His Pacing



His Pacing



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