Hartford HealthCare

Heart & Vascular Institute

His Bundle Pacing

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Disclosures

Dr. Eric Crespo has disclosed a financial relationship with Medtronic.

This relationship may be perceived as a conflict of interest.

Dr. Crespo’s slides were submitted for peer-review and there was no bias noted in his presentation.

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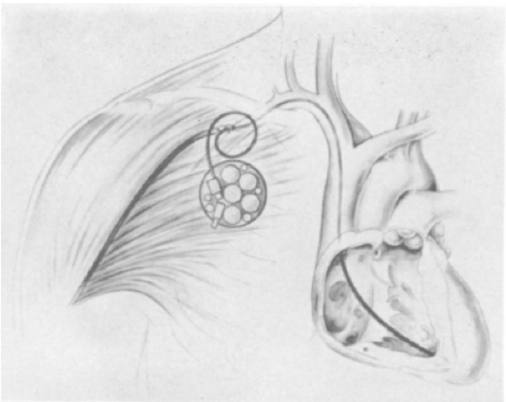
Implanted Transvenous Pacemakers:

Equipment, Technic and Clinical Experience

SEYMOUR FURMAN, M.D., DORIS J. W. ESCHER, M.D.,
NORMAN SOLOMON, M.D., JOHN B. SCHWEDEL, M.D.

From the Divisions of Surgery and Medicine, Montefiore Hospital and Medical Center, Bronx, New York



Presented before the American Surgical Association, March 23–25, 1966, Boca Raton, Fla.

- "Adequate apical positioning cannot be overemphasized, as a non-apical position will often result in intermittent or absent ventricular capture..."

- "...stability of pacing depends on a true apical position..."

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THE MUSCULAR REACTIONS OF THE MAMMALIAN VENTRICLES TO ARTIFICIAL SURFACE STIMULI

CARL J. WIGGERS

From the Physiological Laboratory, Western Reserve University, School of Medicine, Cleveland, Ohio

Received for publication April 20, 1925

"When artificial stimuli are given...the initial slower rise of ventricular pressure is prolonged, the isometric contraction phase is lengthened, the gradient is not so steep, the pressure maximum is lower, and the duration of systole is increased."

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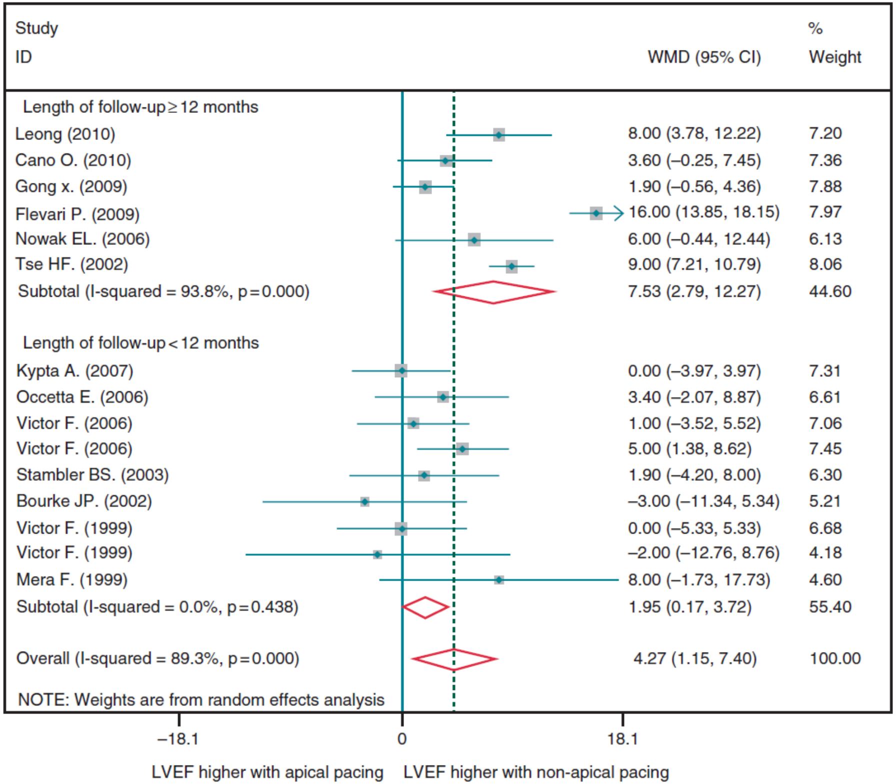
Pacing Induced Cardiomyopathy (PICM)

- MOST: 3 fold increased risk for CHF in those >40% VP
  - HR 2.99 [1.15, 7.75]
- MOST: risk of AF linearly related to % VP increases
- MOST: Risk of PICM >> for paced QRS >160 ms
- DAVID: Frequent V pacing → increased CHF hospitalization (22.6% vs. 13.3%) AND increased mortality (10.1% vs. 6.5%)
- ALTITUDE: %RV pacing associated with increased mortality
  - HR 1.62 for >37% RV pacing (p<0.001)
- Risk for PICM may approach 20% at 10 years, and the threshold for causing PICM may be <40%VP

Sweeney MO, et al. Circulation. 2003;107:2932-37.
Wilkoff et al. JAMA 2002;288:3115-3123
Khurshid A, et al. Heart Rhythm 2014;11:1619-1625

So what about RV septal pacing?

RVA vs. RV Septal Pacing



Simony et al. Europace 2012 14:81-91

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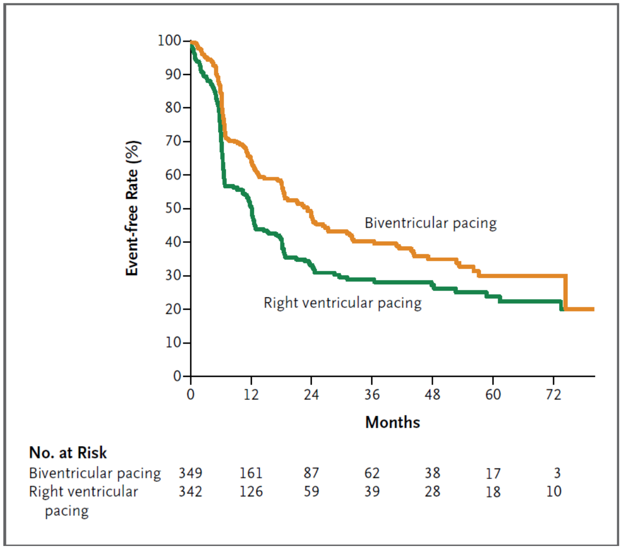
BiV pacing must be better, right?

BLOCK HF: BiV Pacing for AV Block and Systolic Dysfunction



- RCT
- PM for AV Block; EF </=50%
- Dual-PM vs BiV
- 691 patients
- Mean f/u 3 years

- 26% reduction in combined endpoint of death/urgent CHF visit**/>15% increase in LVESVi**

Curtis et al. NEJM 2013;368:1585-93

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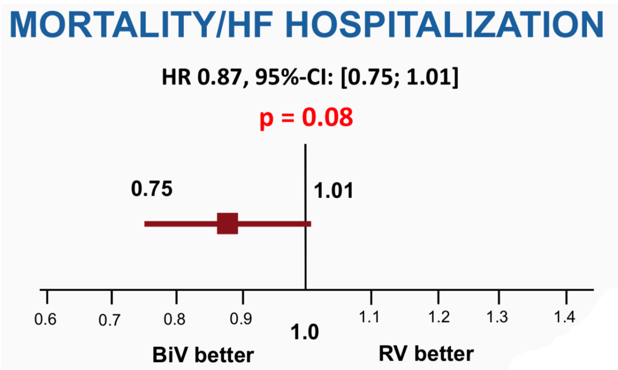
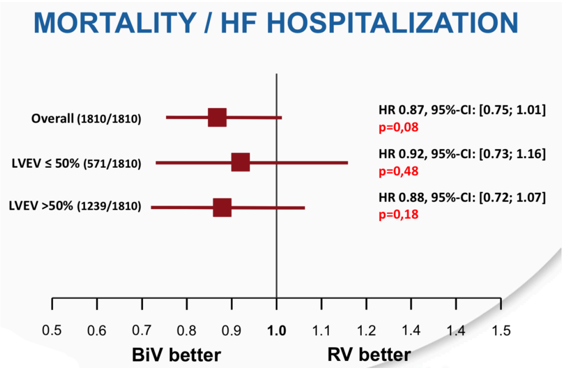
BioPace: BiV Pacing for AV Block to Prevent Cardiac Desynchronization





N=1810

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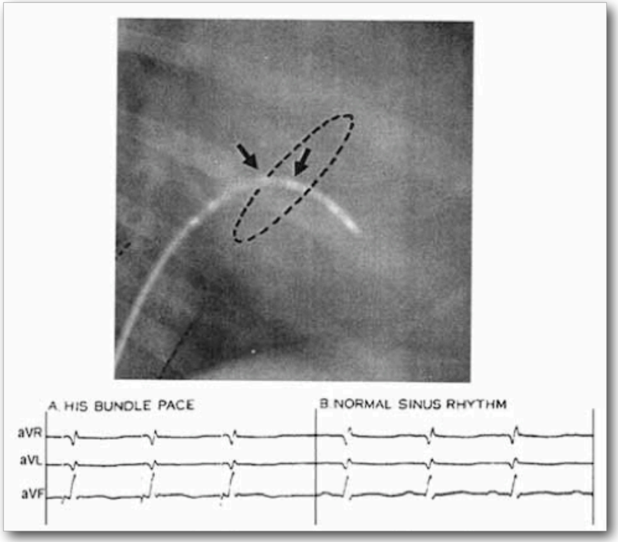
So this is where His Bundle Pacing comes in, right?

Historical Context

- Open-chest - Dogs (Scherlag 1967)
- Transvenous-Dog (Scherlag 1968)
- Temp Transvenous – humans (Narula 1970)
- Permanent HBP- dogs via thoracotomy (Karpawich 1992)
- Permanent HBP – humans, transvenous (Deshmukh 2000)



Scherlag B , et al. A technique for ventricular pacing from the His-bundle of the intact heart. J Appl Physiol. 1967;22:584-589.
Scherlag B, et al. A catheter technique for His-bundle stimulation and recording in the intact dog. J Appl Physiol. 1968;25:425-4825.
Narula O, et al. Pervenous pacing of the specialized conduction systemin man: His-bundle and AV nodal stimulation. Circulation. 1970;41:77-87.
Karpawich P, et al. His-Purkinje ventricular pacing in canines: A new endocardial electrode approach. PACE. 1992;15:2011-2015.
Deshmukh P, et al. Permanent Direct His-Bundle Pacing: A Novel Approach to Cardiac Pacing in Patients with Normal His-Purkinje Activation. Circulation. 2000;101:869-877.

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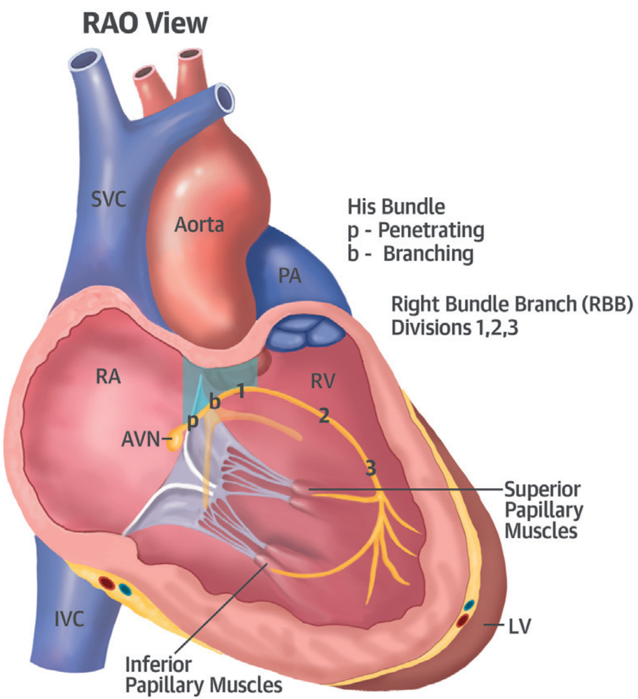
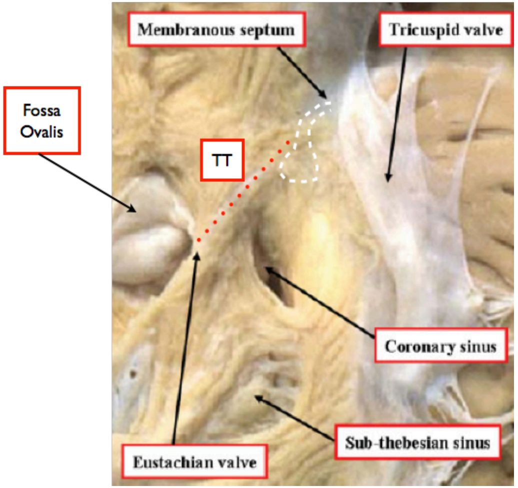
Anatomy





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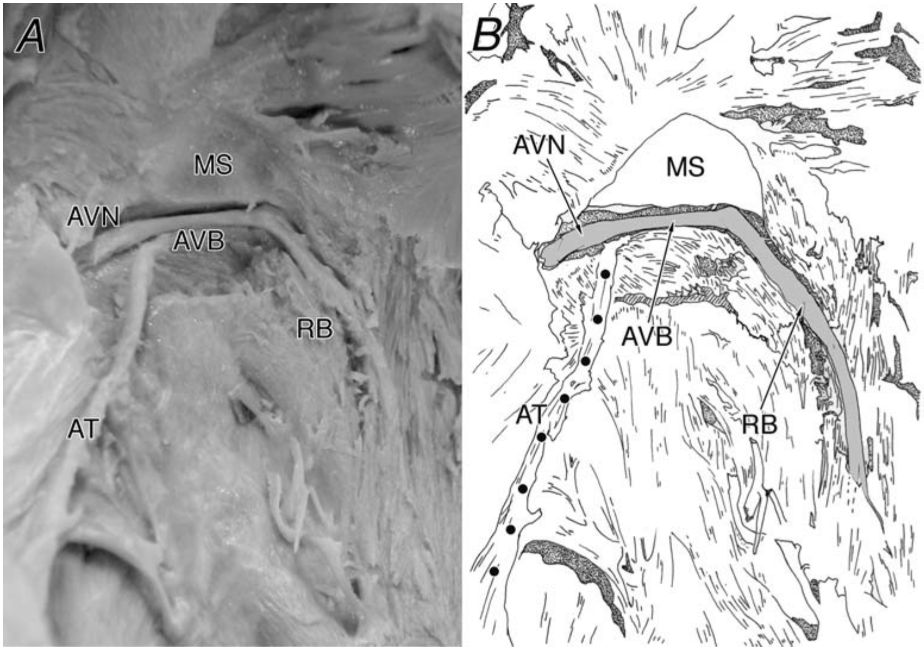
Type I ~47%



Kawashima et al. A Macroscopic anatomical investigation of the atrioventricular bundle locational variation relative to the membranous septum in elderly human hearts. Surg Radiol Anat 2005;27:206-213.
Dandamud et al. The complexity of the His bundle: Understanding its anatomy and physiology through the lens of the past and the present. PACE 2016;39:1294-1297.

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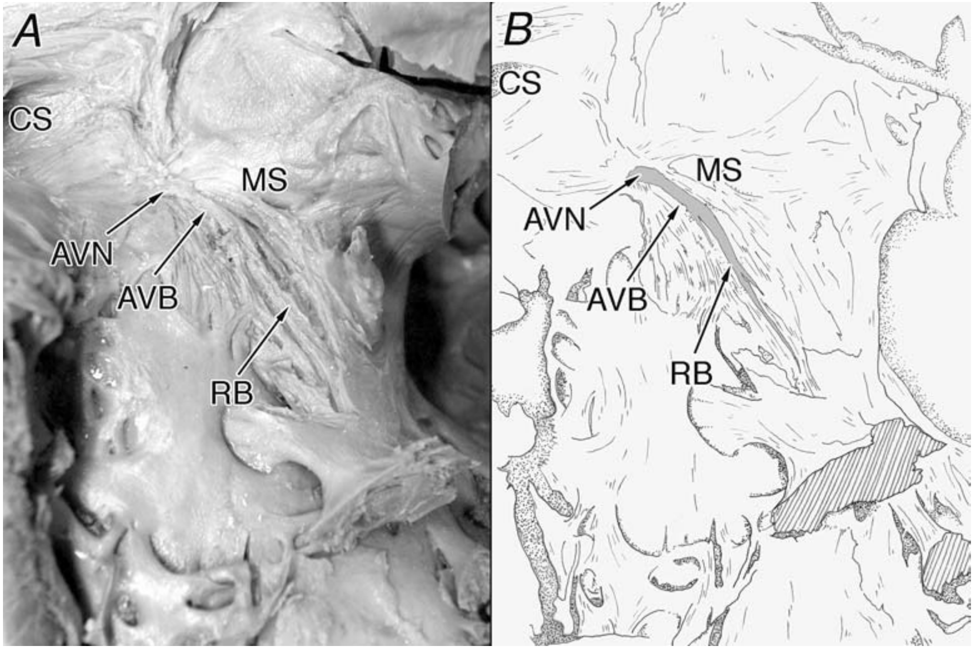
Type II ~32%



Kawashima et al. A Macroscopic anatomical investigation of the atrioventricular bundle locational variation relative to the membranous septum in elderly human hearts. Surg Radiol Anat 2005;27:206-213.
Dandamud et al. The complexity of the His bundle: Understanding its anatomy and physiology through the lens of the past and the present. PACE 2016;39:1294-1297.

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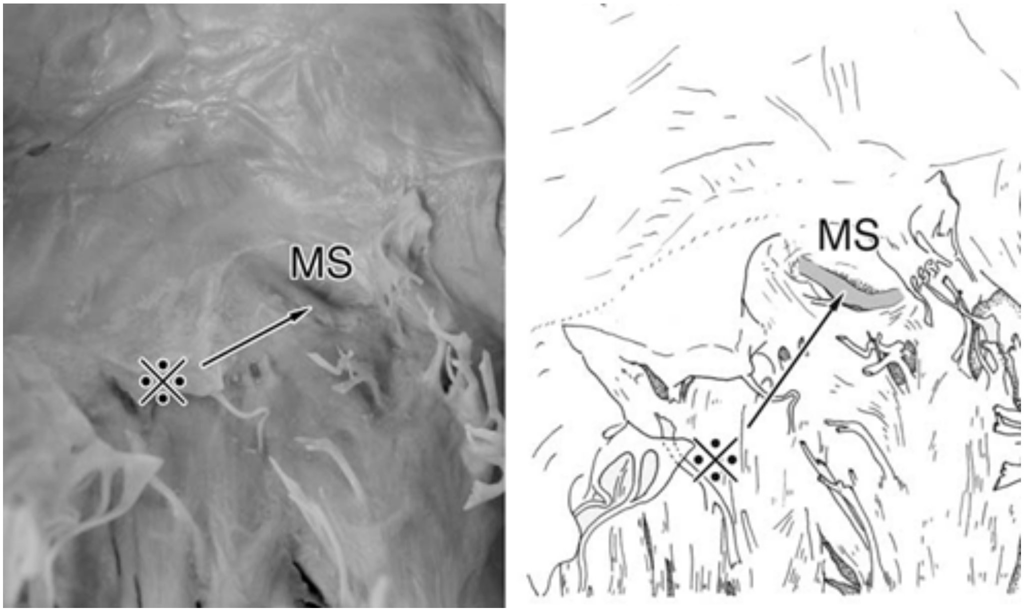
Type III ~21%



Kawashima et al. A Macroscopic anatomical investigation of the atrioventricular bundle locational variation relative to the membranous septum in elderly human hearts. Surg Radiol Anat 2005;27:206-213.

Dandamud et al. The complexity of the His bundle: Understanding its anatomy and physiology through the lens of the past and the present. PACE 2016;39:1294-1297.

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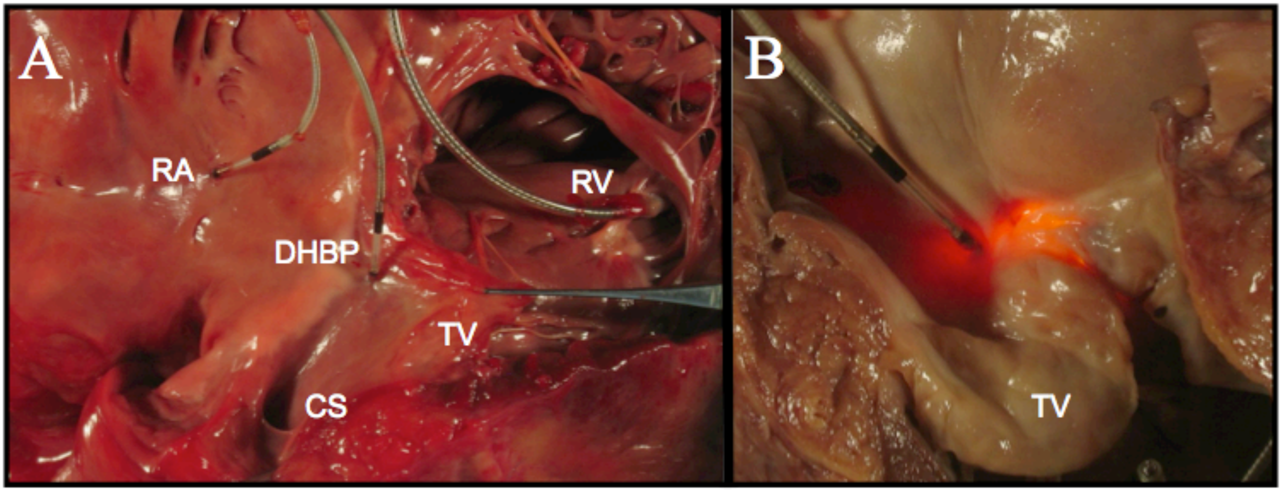

Correa de Sa D, Hardin N, Crespo E, Nicholas K, Lustgarten D. Analysis of the Implantation Site of a Permanent Selective Direct His Bundle Pacing Lead at Autopsy. 2011. Circulation Arrhythmia and Electrophysiology..

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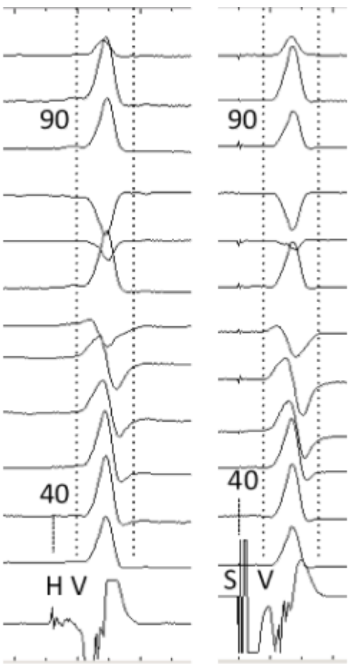
Responses to His Bundle Pacing

Selective His Bundle Pacing (S-HBP)

Capture of His ONLY

- Isoelectric interval from Stim to QRS onset
  - Stim-V ≅ H-V
- Paced QRS identical to native QRS
- Single capture threshold



Vijayaraman. Heart Rhythm. 2017. In press

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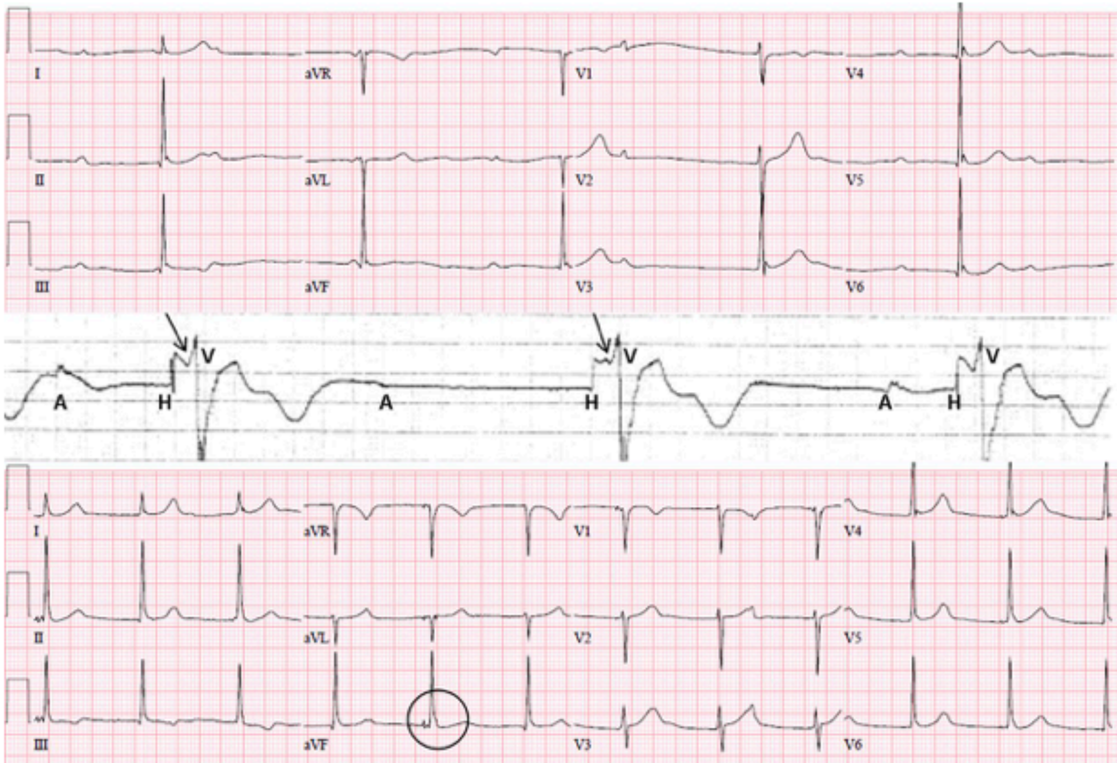
S-HBP



Vijayaraman et al. JACEP 2015;1:571-581.

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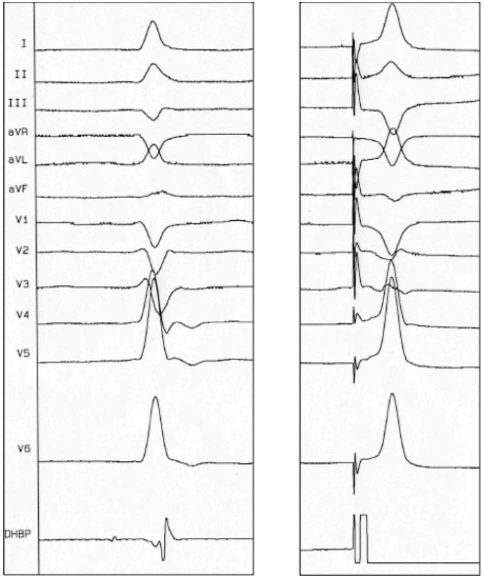
Non-Selective His Bundle Pacing (NS- HBP)

Simultaneous capture of His AND basal RV

- S-QRS < HV (usually 0)
- "pseudo-delta wave"
- Paced QRS > Native QRS
  - Rapid components of QRS are identical to native
  - Electrical axis concordant with intrinsic QRS
- 2 distinct capture thresholds:
  - His Capture + RV Capture



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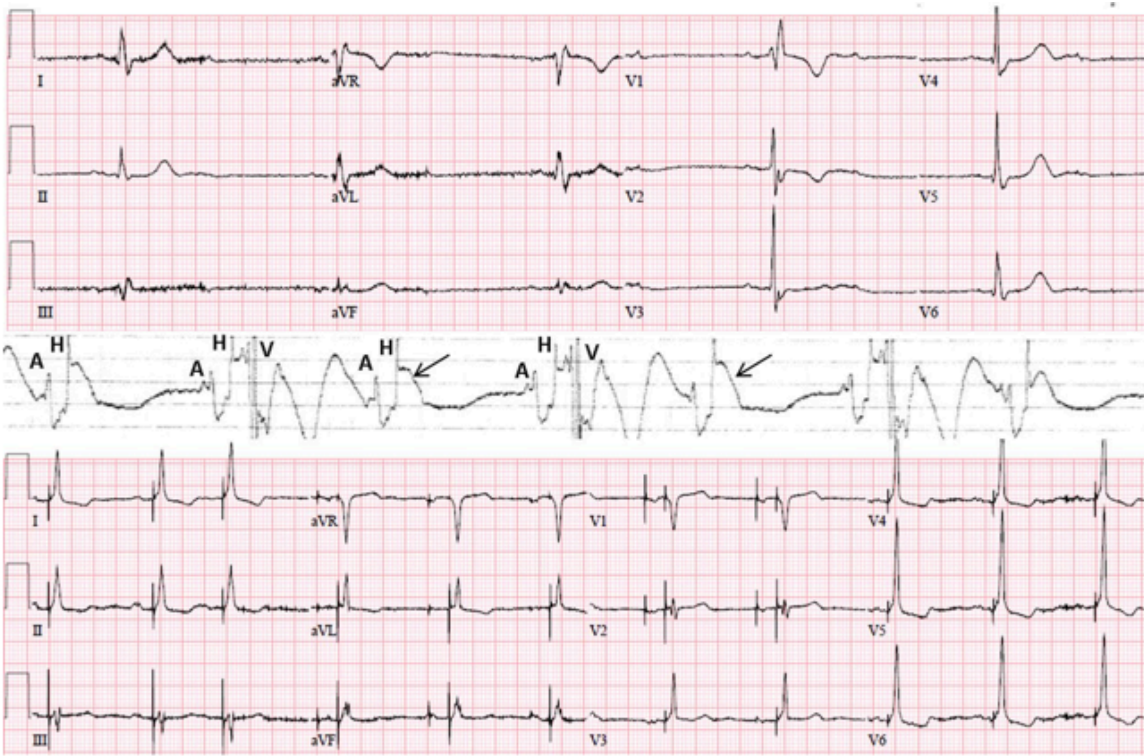
NS-HBP



Vijayaraman et al. JACEP 2015;1:571-581.

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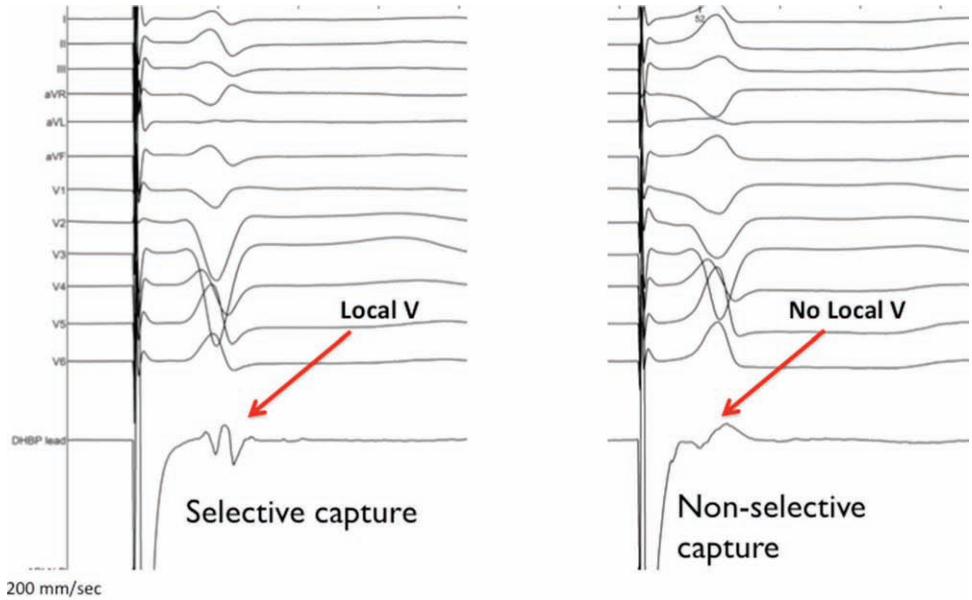
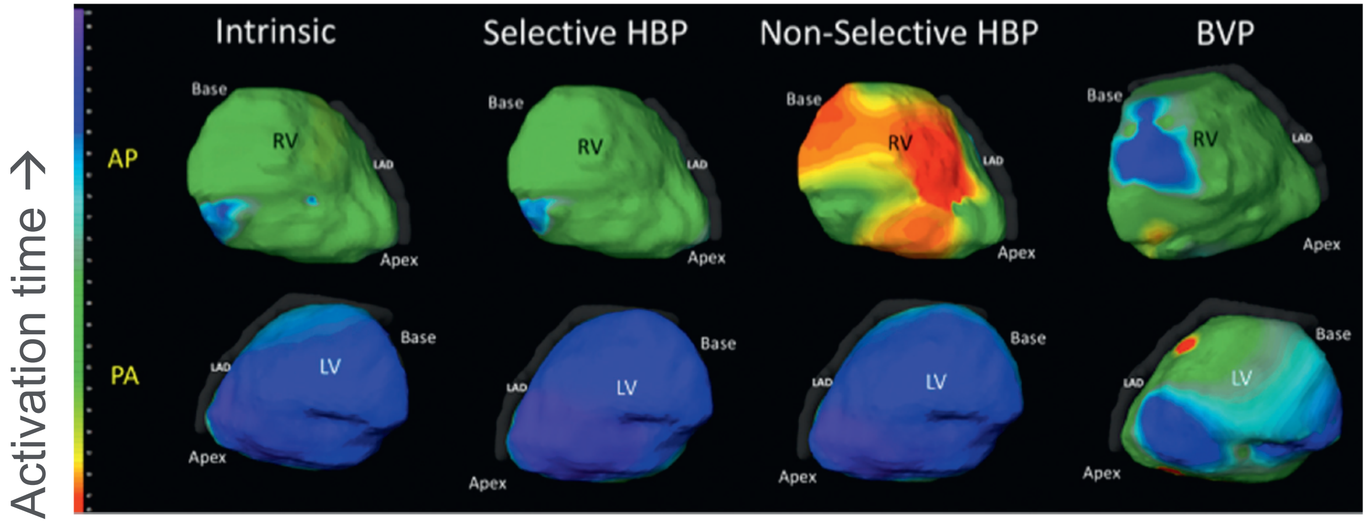
S-HBP vs. NS-HBP: Look at septal V



Lustgarten DL. Journal of Innovations in Cardiac Rhythm Management. 2016;7:2313-2321

HBP activates the ventricles the same as native conduction

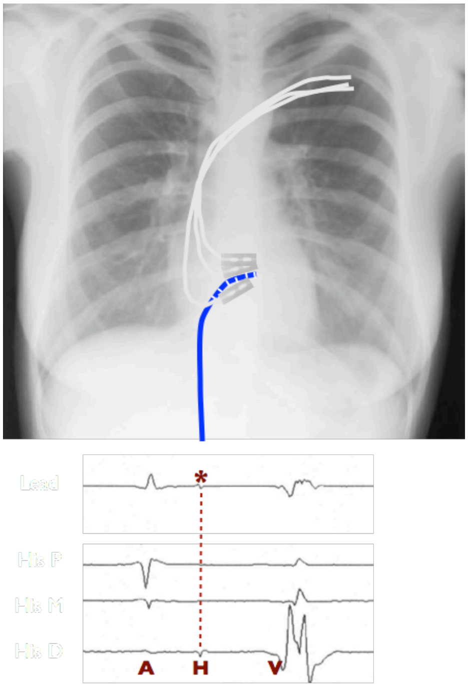


Vijayaraman et al. JACC. 2018;72:927-47.

Early Studies of HBP

Deshmukh 2000 - Permanent HBP in Humans

- HBP prior to AV node ablation
- Mapping catheter via femoral vein to localize His Bundle
- Active fix, stylet-driven lead
- Iterative stylet adjustments to direct lead to His bundle region
- Procedure time: 3.7 ± 1.6 hrs (including AV node ablation)



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Deshmukh 2000 - Permanent HBP in Humans

Pacing Parameter	Acute (N = 12)
Native QRS (ms)	95 ± 13
Paced QRS (ms)	92 ± 11
Sensed R wave (mV)	1.7 ± 0.8
Threshold	2.4 ± 1.0 V @ 0.5 ms
Impedance	488 ± 86

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Deshmukh 2000 - Permanent HBP in Humans

Echo Parameter	Acute	Last F/U (Mean 23.4 ± 8.3 months)
LVEDD (mm)*	59 ± 8	52 ± 6
LVESD (mm)*	51 ± 10	43 ± 8
LVEF (%)*	18 ± 10	29 ± 11

* $P \leq 0.05$
N = 11

Deshmukh 2004 - Expanded Case Series

- HBP successful 39/54 (72%)
- Mean f/u 42 months
- No QRS widening
- EF increased from 23% to 33%
- Stable pacing parameters

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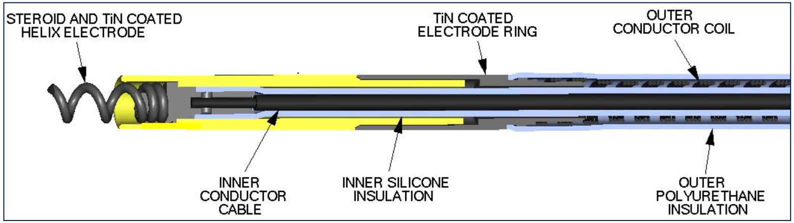
3830 SelectSecure Lead

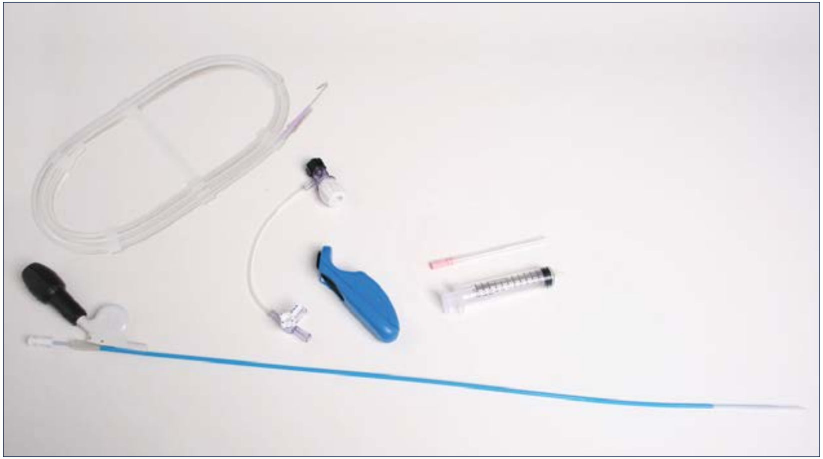
3830 Lead

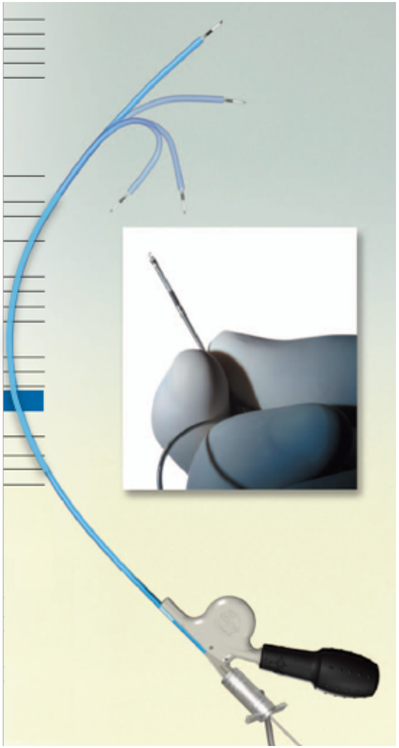
3830 Lead Specifications:

- 4.1 FR lead body diameter
- Bipolar
- Fixed screw helix
- Steroid eluting
- Polyurethane outer insulation
- Cable inner conductor
  - **Use 69 cm lead for His pacing**



C304 Deflectable Guide Catheter





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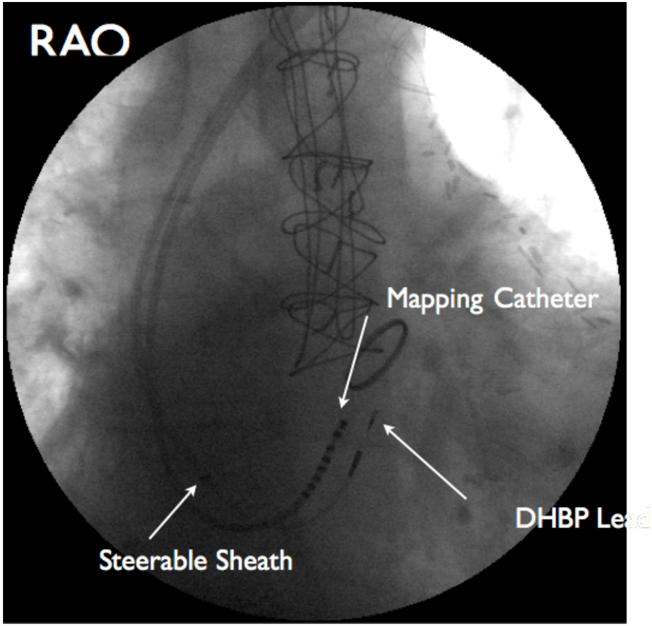
Zanon 2006: HBP using 3830

- 26 patients
  - 2nd or 3rd degree AVB
  - Narrow QRS
- Successful HBP in 24 (92%)
- Procedure time = 75 +/- 18 min
- Fluoro time = 11 +/- 8 min
- Threshold: 2.3 +/- 1V



Zanon F, et al. A Feasible Approach for Direct His Bundle Pacing Using a New Steerable Catheter to Facilitate Precise Lead Placement. J Cardiovasc Electrophysiol. 2006;17:29-33..

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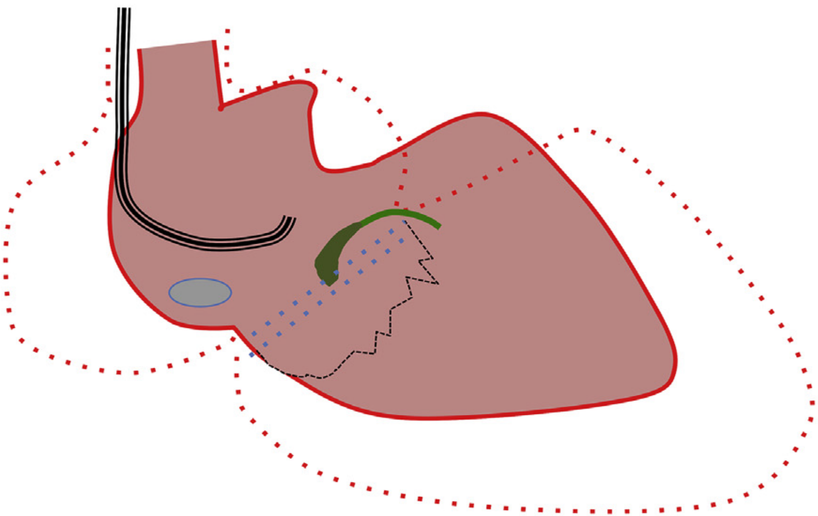
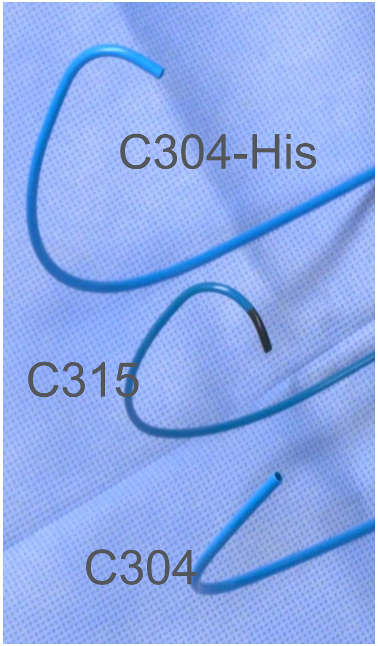
C315His Guide Catheter

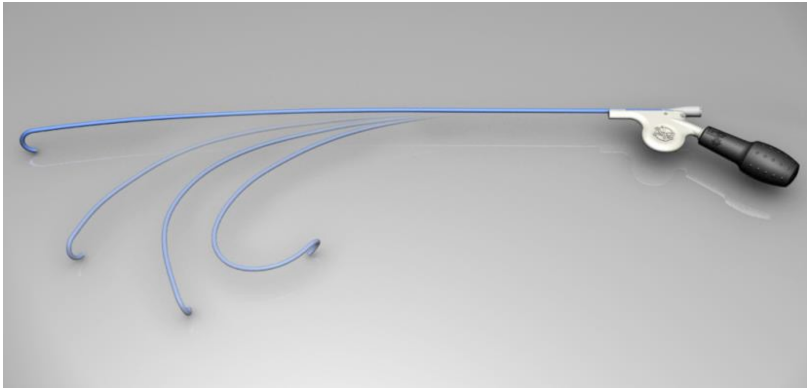
Dilated RA/RV Can Be Challenging



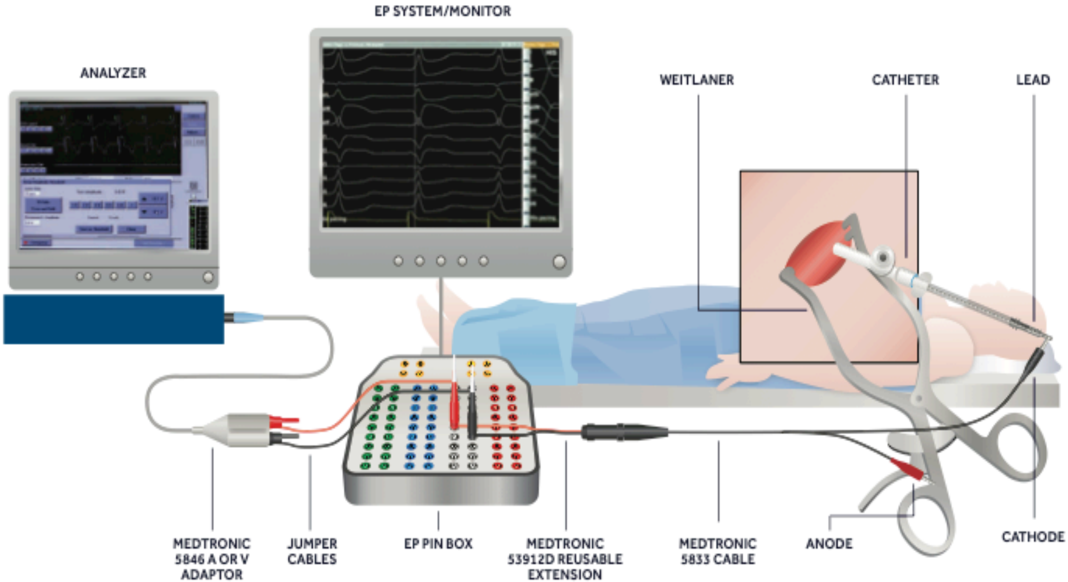
Vijayaraman et al. Heart Rhythm. 2018;15:1428-1431.

C304-His Deflectable Guide Catheter





Set Up – Getting Signal to PSA & EP Recording System



Label	Type	Inputs		Gain	Filter Settings	
		+	-		High Pass	Low Pass
HIS d	Bipolar	6	5	10,000	30.00 Hz	500 Hz
HIS m	Bipolar	6	5	5,000	0.50 Hz	500 Hz

For optimal viewing:
Adjust the gain to the highest setting without observing artifact.
See example on the left of filter settings for His d and His m.

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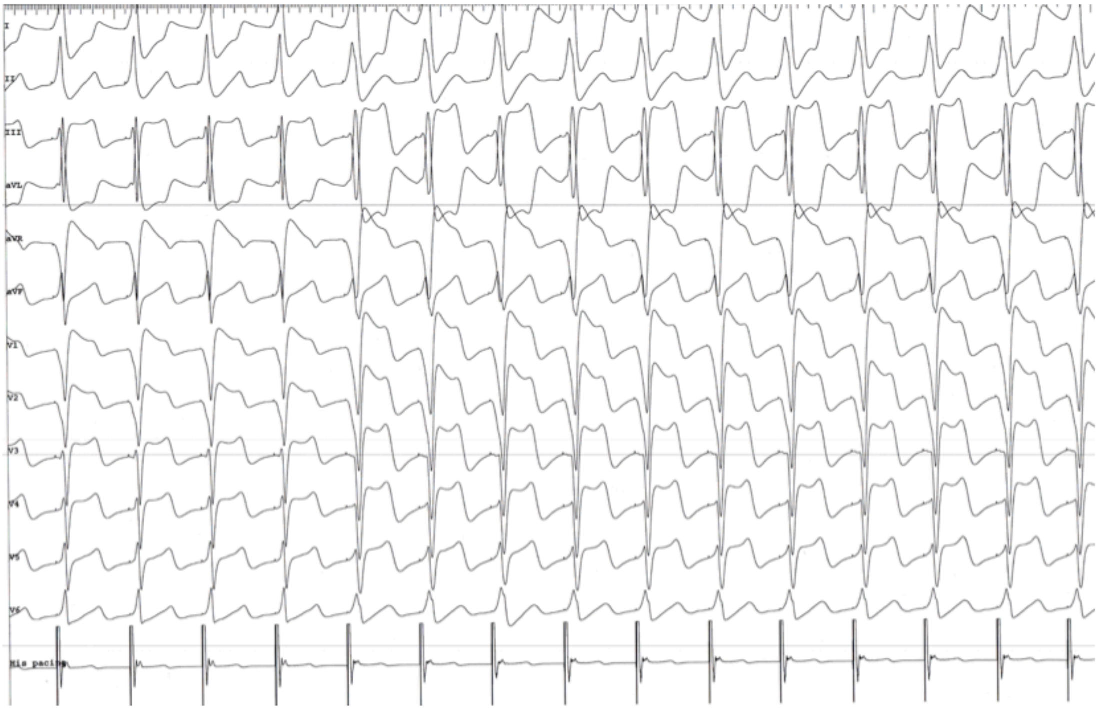
NS-HBP to RV Only



1.75V → 1.5V

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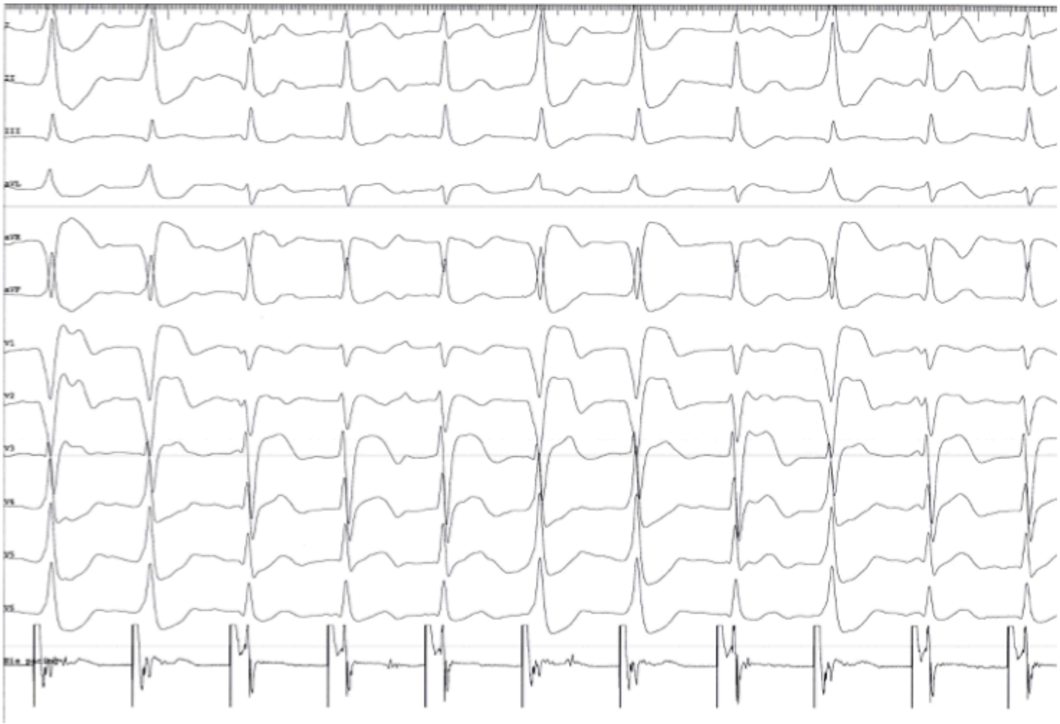
NS-HBP → S-HBP → NS-HBP → S-HBP



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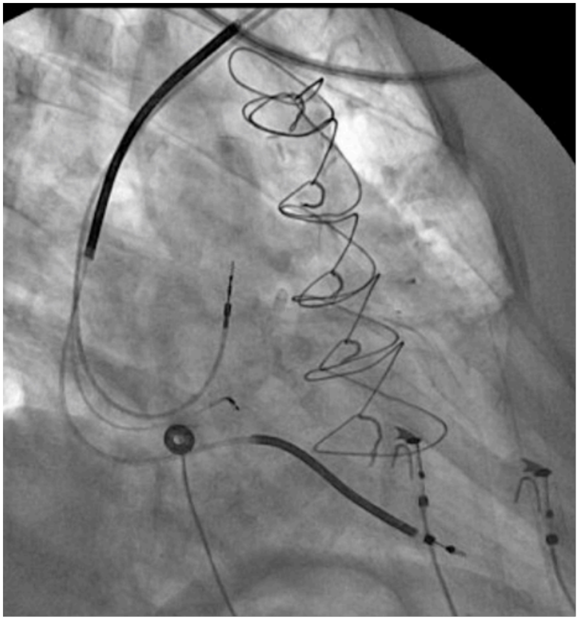
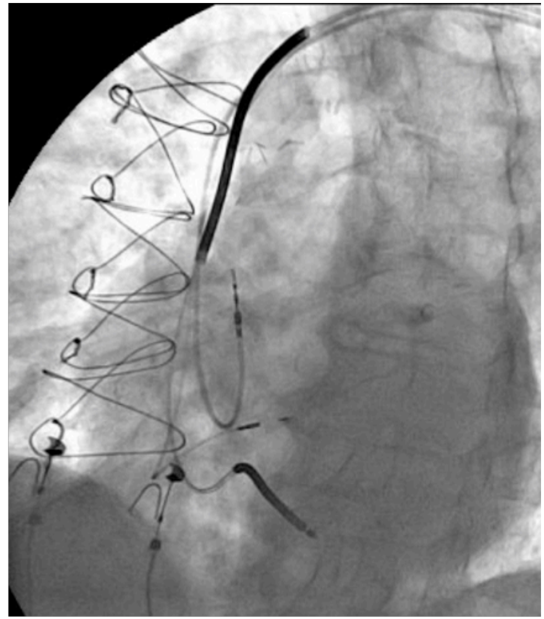


RAO



LAO

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Issues/Limitations

- Learning curve 10-20 cases.
  - Procedure times will decrease with experience
- Unsuccessful in ~10-15% of cases
- Thresholds may increase in ~10%
- Lead revision 3-5%
- Complete AV block ~1%
- Permanent RBBB ~3%?
- Battery drain

HBP: Current Data

TABLE 4 Hemodynamics of Permanent HBP

First Author, Year (Ref. #)	N	Acute Success	Follow-Up	Results
Catanzariti et al., 2006 (53)	24	23 (96%)	7.5 months	• Compared with RVA pacing, selective or nonselective HBP is associated with lower interventricular dyssynchrony, intraventricular dyssynchrony, MR, and better myocardial performance index (Tei index) • No difference between selective or nonselective HBP
Zanon et al., 2008 (19)	12		3-month HBP crossover to RVA pacing	• Patients with preserved HPS conduction • Myocardial scintigraphy, QoL, clinical evaluation, echo, BNP • Perfusion score, Short Form-36 physical and mental status significantly better during HBP than during RVAP • No difference in NYHA functional class, BNP, mean LVEF, LV volumes • Less MR and mechanical dyssynchrony during HBP • One-half of RVAP had dyssynchrony, none during HBP
Catanzariti et al., 2013 (20)	26	20 SHBP 6 NSHBP	34 months Crossover at end to RVA	• Patients with HBP and backup RVA lead • At last follow-up, mean paced QRSd NS from baseline at implant • At mean of 346 months, pacing switched to RVA with decrease in LVEF 57.3% to 50.1%, increase in MR, worsened interventricular delay, and tissue Doppler imaging asynchrony index, although no change in myocardial performance index • Higher pacing thresholds on the His bundle compared with RVA lead (mean 18 V vs. 06 V at 05 ms), but stable from implant
Kronborg et al., 2014 (40)	38	84% HBP	12-month crossover, HBP vs. RVSP	• Narrow QRS <120 ms c AVB, LVEF >40% • HBP preserved LVEF and mechanical synchrony (time to peak systolic velocity between opposite basal segments) compared with RVSP • No difference in NYHA functional class, 6MWT, QoL, or complications • Mean threshold higher in HBP than RVSP leads
Pastore et al., 2014 (58)	37		3-month crossover from HBP to RVA pacing	• Compared with HBP, RVA pacing increased systolic-diastolic electromechanical delay, intra-LV dyssynchrony, LV isovolumetric contraction, and relaxation times; LV ejection time was shorter • HBP had better myocardial performance index and diastolic function, lower PASP • RVA pacing had higher LA volumes pre-atrial contraction and minimal volume with reduction in passive emptying fraction and total emptying fraction • Hisian area compared with RVA pacing resulted in a more physiological LV electromechanical activation/relaxation and consequently better LA function
Zhang et al., 2017 (33)	23	NSHBP 11 SHBP 12 RVSP 23	HBP vs. RVSP Intrapatient	• Mechanical synchrony parameters were significantly better during HBP compared with RV septal pacing with no significant difference between S-HBP or NS-HBP

Vijayaraman et al. JACC. 2018;72:927-47.

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TABLE 2 Permanent His Bundle Pacing in AV Node Ablation/AV Block

First Author, Year (Ref. #)	Design	Follow-up (Months)	N	Indication	Success (%)	Important Characteristics	Outcomes
Deshmukh et al., 2000 (5)	Observational	36	18	AV node ablation	66	Chronic AF, LVEF <40%, QRS duration <120 ms	Improvement in LV dimensions, NYHA functional class, and LVEF
Deshmukh et al., 2004 (35)	Observational	42	54	AV node ablation	72	Chronic AF, LVEF <40%, QRS duration <120 ms	Improved LVEF, NYHA functional class, peak VO_2
Occhetta et al., 2006 (36)	Randomized, 6 months, crossover RVP vs. HBP	12	18	AV node ablation	94	Chronic AF, QRS <120 ms	Improvement in NYHA functional class, 6MWT, QOL, and hemodynamics
Huang et al., 2017 (28)	Observational	20	52	AV node ablation	81	Chronic AF, CHF	Improvement in LV dimensions, NYHA functional class, and LVEF
Vijayaraman et al., 2017 (37)	Observational	19	42	AV node ablation	95	Paroxysmal or persistent AF, CHF	Improvement in NYHA functional class, LVEF
Barba-Pichardo et al., 2010 (41)	Prospective	>3	91	AV nodal 65 Infranodal 26	68 57	182 patients with AV block mapped with EP catheter	5% lead failure
Kronborg et al., 2014 (40)	Randomized crossover HBP vs. RVSP	24	38	AV nodal block	84	AV block, baseline narrow QRS, LVEF >40%	Improvement in LVEF, no significant improvement in functional class, 6MWT, QOL
Pastore et al., 2015 (58)	Retrospective	12	148	AV nodal 100 Infranodal 48		High-grade AVB, Paroxysmal AF	HBP associated with lower risk of AF progression compared with RV pacing
Vijayaraman et al., 2015 (29)	Observational	19	100	AV nodal 46 Infranodal 54	93 76	High-grade AV block, no back-up RV pacing	High success in infranodal block. Lead failure 5%

Vijayaraman et al. JACC. 2018;72:927-47.

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Permanent His-bundle pacing is feasible, safe, and superior to right ventricular pacing in routine clinical practice

Parikshit S. Sharma, MD, MPH,* Gopi Dandamudi, MD, FHRS,*
Angela Naperkowski, RN, FHRS, CCDS, CEPS,* Jess W. Oren, MD,† Randle H. Storm, MD, FHRS,†
Kenneth A. Ellenbogen, MD, FHRS,‡ Pugazhendhi Vijayaraman, MD, FHRS*

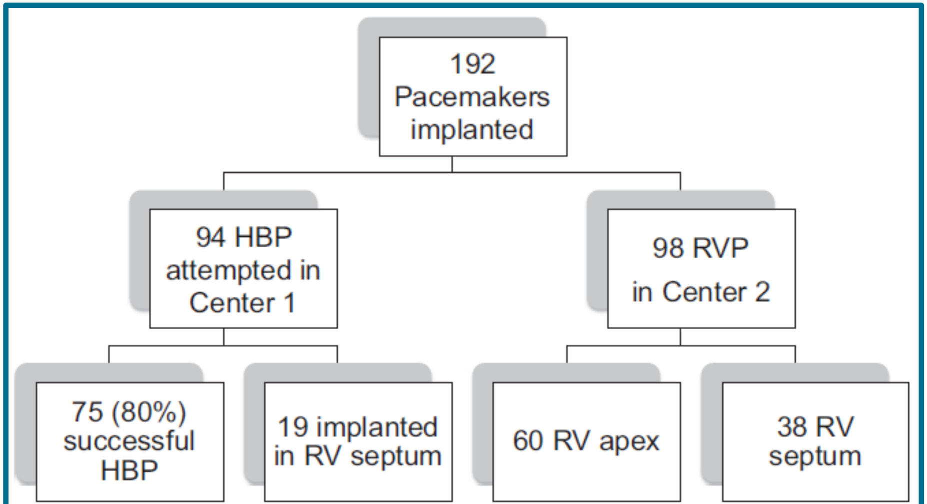

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Table 2 Procedural outcomes

Parameter	His-bundle pacing	RV pacing	*P*
No. of patients	75	98	
Dual-chamber implants	65 (87)	81 (83)	NS
Baseline QRS duration (ms)	109 ± 26	102 ± 24	NS
Paced QRS duration (ms)	124 ± 22	168 ± 21	.001
Fluoroscopy duration			NS
Mean (min)	12.7 ± 8	10 ± 14	
Median (min)	9.1	6.4	
Procedure duration			<.01
Mean (min)	79 ± 25	64 ± 25	
Median (min)	75	58	
Patients with >40% ventricular pacing	47 (63)	60 (62)	NS
R wave amplitude (mV)	6.8 ± 5.3	13.7 ± 5.7	<.05
Pacing impedance (Ω)	639 ± 159	754 ± 167	<.05
Pacing thresholds (V at 0.5 ms)			
Implantation	1.35 ± 0.9	0.62 ± 0.5	<.001
2 wk	1.50 ± 1.1	0.73 ± 0.2	<.001
1 y	1.60 ± 0.9	0.80 ± 0.3	<.001
2 y	1.50 ± 0.8	0.80 ± 0.4	<.001

Values are presented as mean ± SD or as n (%).
NS = not significant; RV = right ventricular.

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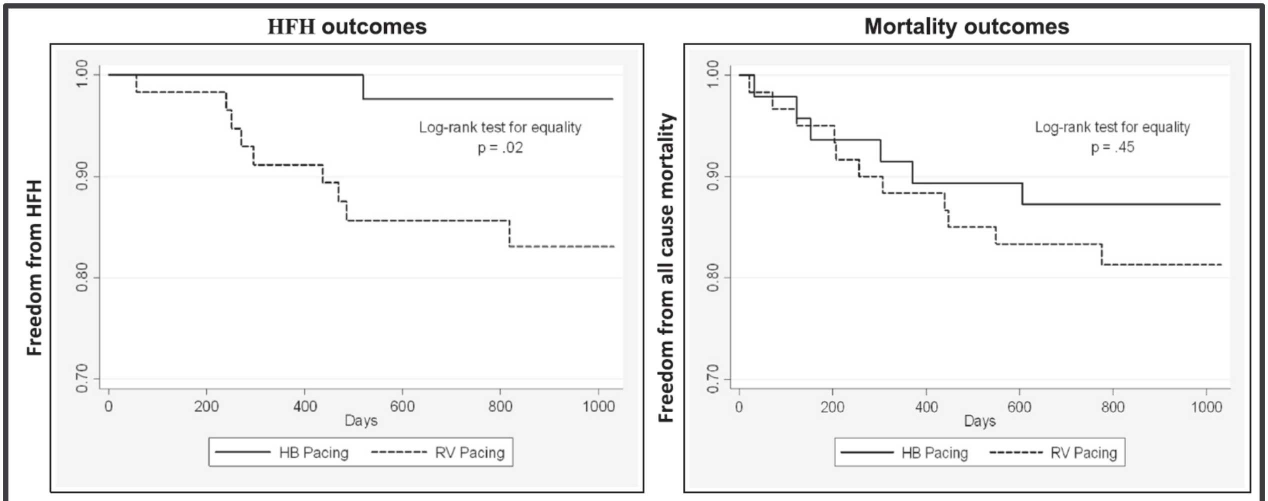
Angela Naperkowski, RN, FHRS, CCDS, CEPS,* Jess W. Oren, MD,† Randle H. Storm, MD, FHRS,†
Kenneth A. Ellenbogen, MD, FHRS,‡ Pugazhendhi Vijayaraman, MD, FHRS*



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Permanent His Bundle Pacing: Long-Term Lead Performance and Clinical Outcomes

Pugazhendhi Vijayaraman, MD, FHRS, Angela Naperkowski, RN, CEPS, CCDS, FHRS, Faiz A. Subzposh, MD, Mohamed Abdelrahman, MD, Parikshit S. Sharma, MD, MPH, Jess W. Oren, MD, MD, FHRS Gopi Dandamudi, Kenneth A. Ellenbogen, MD, FHRS

Published on-line January 2018

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Table 1: Electrical parameters

	RVP				HBP			
Visit	**n**	**Threshold V**	**R wave mV**	**Impedance Ohms**	**n**	**Threshold V**	**R wave mV**	**Impedance Ohms**
Implant	98	0.62±0.5	13.7±5.7	754±167	75	1.35 ±0.9*	6.8±5.3*	639±159
1 year	88	0.80+-0.3	12.7±5.6	585±128$^{\#}$	66	1.60±0.9*	6.7±5.7*	476±121$^{\#}$
2 years	77	0.80±0.4	15.2±6.6	515±136	61	1.50±0.8*	7.0±6.0*	465±75
5 years	58	0.84±0.4$^{\#}$	13.3±5.7	468±117	51	1.62±1.0*$^{\#}$	7.2±5.2*	463±78

Pacing threshold tested at 0.5 ms pulse duration; * = p-value <0.01 versus RVP;

= p-value <0.05 versus implant; HBP – His bundle pacing; RVP – right ventricular

pacing; n – number

Table 2: ECG Characteristics

	RVP	HBP	p value
Number of patients	98	75	
Baseline QRSd (ms)	102±24	109±26	0.07
Paced QRSd (ms) - implant	168±21	124±22	**<0.01**
Ventricular pacing >40%			
Number of patients, n (%)	60 (62%)	47 (63%)	0.44
QRSd at baseline	108±27	109±24	0.12
QRSd at implant	165±26	122±21	**<0.01**
QRSd at 2 years, (n)	168±29 (43)	125±23 (40)	**<0.01**
QRSd at 5 years, (n)	170±31 (26)	126±29 (31)	**<0.01**

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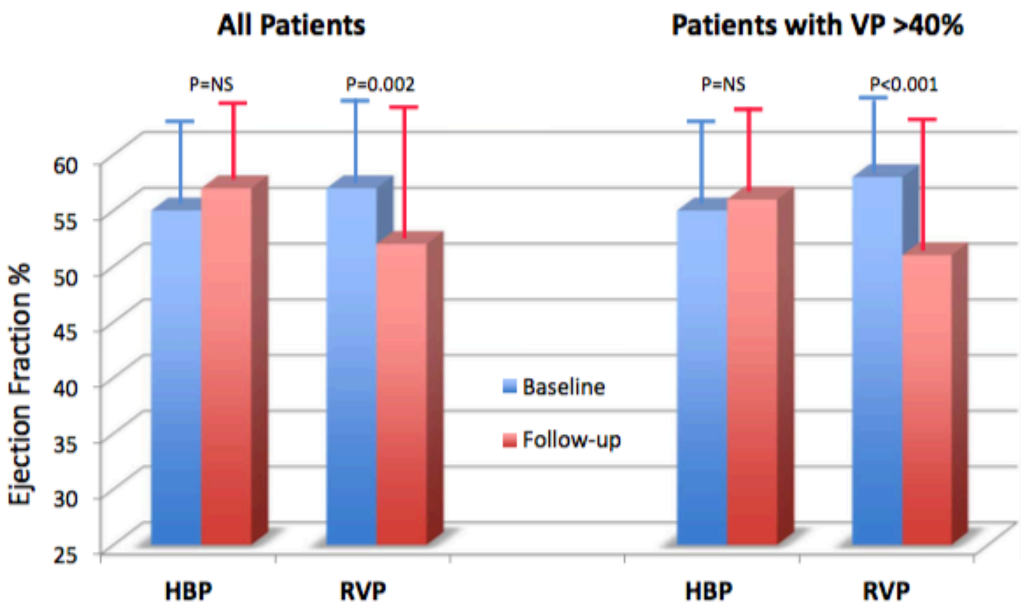
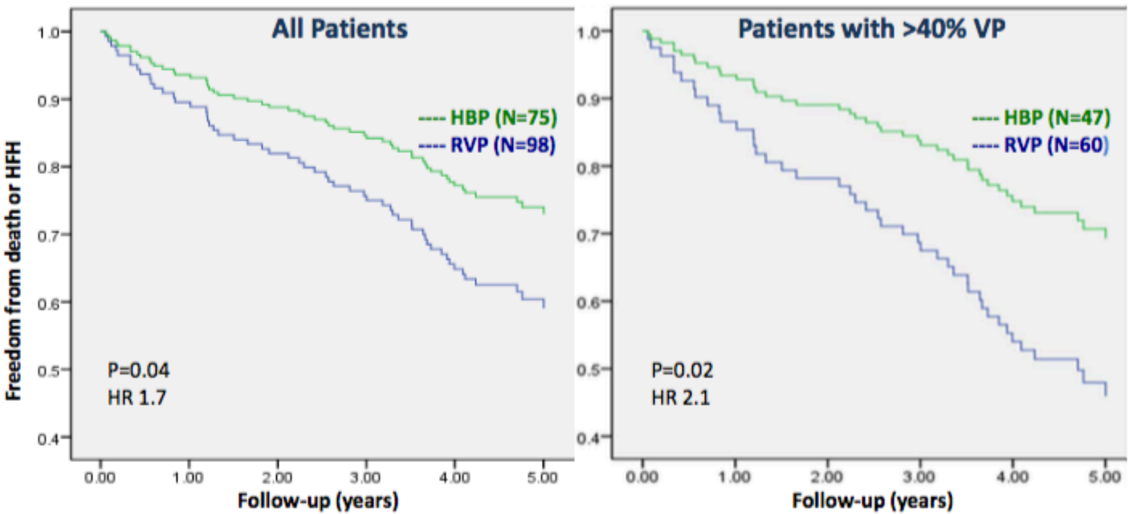


RVP: 18 patients had >10% decline in EF

Combined End-point of Death or Heart Failure Hospitalization



On Treatment

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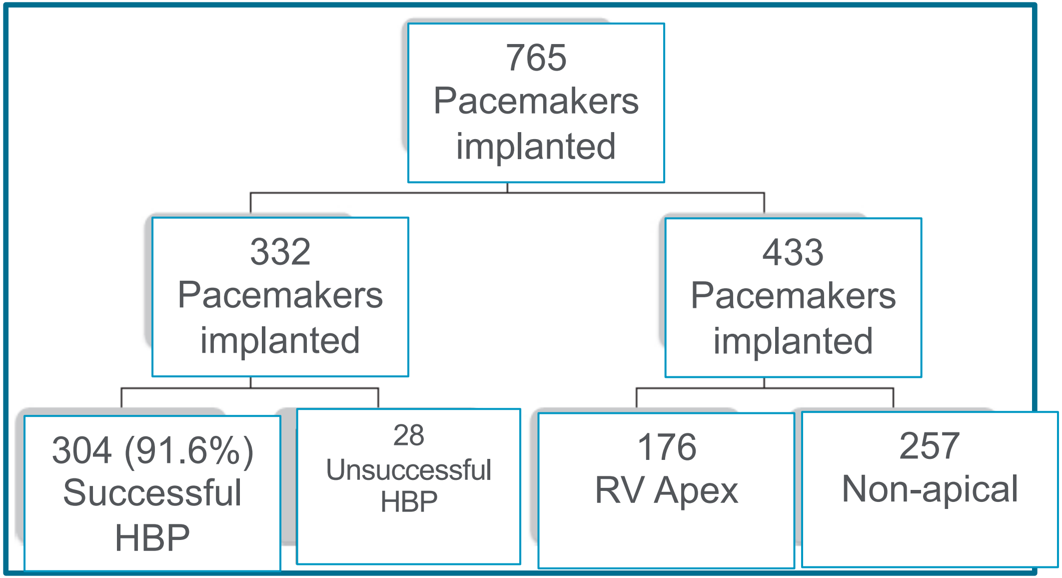
JACC: March 2018



Abdelrahman M, et al. Clinical Outcomes of His Bundle Pacing Compared to Right Ventricular Pacing. JACC. Published on-line March 2018

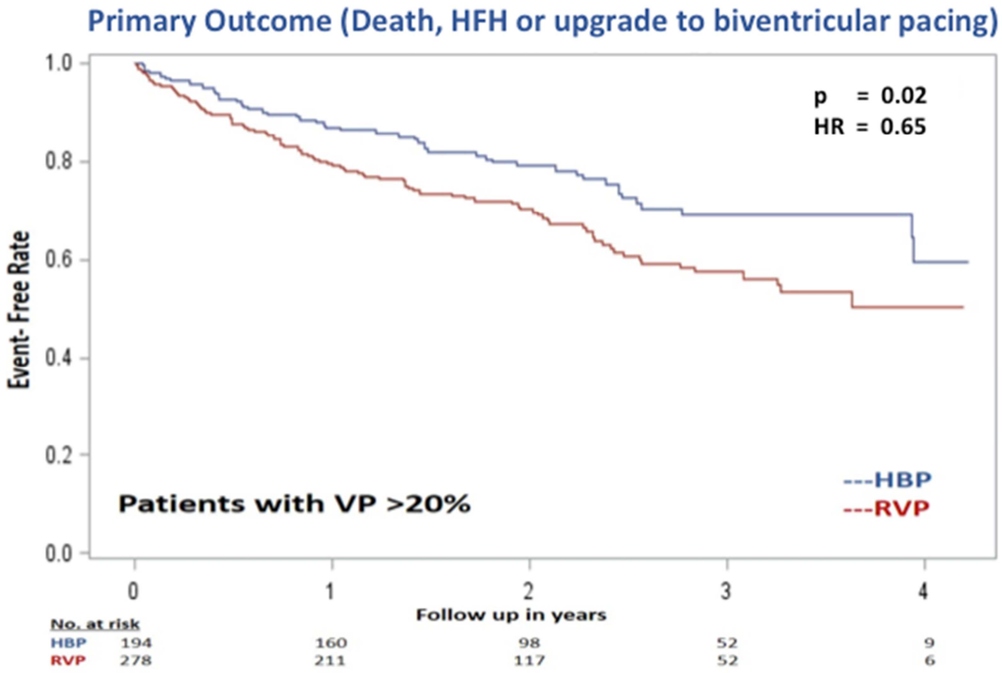
Clinical Outcomes of HBP Compared to RV Pacing

Table 2: Procedural and Pacing Characteristics

		His Bundle Pacing (N=304)	**RV pacing (N=433)**	P-value
	Procedure duration (min), mean (SD)	70.21 (34)	55.02 (25)	**< 0.01**
	Fluoroscopy duration (min), mean (SD)	10.27 (6.5)	7.40 (5.1)	**< 0.01**
Measurements at implant	**QRS duration (ms),** mean (SD)	104.5 (24.5)	110.5 (28.4)	**< 0.01**
	Capture threshold (V @ ms), mean (SD)	1.30 (0.85) @ 0.79 (0.26)	0.59 (0.42) @ 0.5 (0.03)	**< 0.01**
	R wave amplitude (mV), mean (SD)	4.93 (3.46)	11.24 (6.37)	**< 0.01**
	Ventricular impedance (Ohms), mean (SD)	550 (126)	723 (162)	**< 0.01**
Measurements at last follow-up	**QRS duration (ms),** mean (SD)	128 (27.7)	166 (21.8)	**< 0.01**
	Capture threshold (V @ ms), mean (SD)	1.56 (0.95) @ 0.78 (0.30)	0.76 (0.29) @ 0.46 (0.09)	**< 0.01**
	R wave amplitude (mV), mean (SD)	5.54 (5.0)	11.7 (5.5)	**< 0.01**
	Ventricular Impedance (Ohms), mean (SD)	456 (68)	517 (116)	**< 0.01**
	Change in threshold (V), mean (SD)	0.28 (1.1)	0.16 (0.5)	0.09

values are mean (SD = standard deviation); RV = right ventricle
V = voltage; ms = millisecond; mV = millivolt.

Clinical Outcomes of HBP Compared to RV Pacing



Parameters Remain Stable During Follow-Up

					At implant								At generator change			
Pt #	Age	Sex	Comorbidities	Indication	HV (ms)	QRSd (ms)	HBP QRSd (ms)	HBP type	HBP threshold @0.5 ms	EF (%)	Time to generator change (m)	HBP pacing %	HV (ms)	HBP QRSd (ms)	HBP threshold @0.5 ms	EF (%)
1	78	M	HTN, HF, CAD, AF	AVB, AF	45	92	120	NS	2.75	35	102	99.6	45	124	3	54
2	70	M	HTN, CAD, AF	AVB, SSS	45	90	100	S	1.6	50	101	98	45	102	2.2	60
3	87	M	HTN	AVB	50	92	92	S	1.2	65	79	96	50	96	1.5	64
4	34	M	CAD, ICM	LBBB, CHF	50	142	100	S	1.6	25	41	85	50	102	2.2	41
5	87	M	HTN, CAD, ICM, AF	AVB, CHF, RVP	45	180	130	NS	1.25	20	38	99.2	45	136	2	44
6	93	M	HTN, CAD, ICM	AVB	45	86	92	S	1.2	58	67	100	45	86	2	44
7	51	M	AF	AVB, SSS	40	92	92	S	1.7	55	84	99	40	94	1.75	55
8	83	F	HTN, AF	AVB, AF	40	92	132	NS	1.5	65	91	98.9	40	136	2	63
9	76	F	AF	SSS	40	120	160	NS	3.6	57	60	18.3	40	150	2	60
10	84	M	HTN	AVB	50	90	130	NS	3.4	55	99	99.8	50	132	3.5	55
11	89	F	HTN, AF	SSS	40	100	130	NS	0.5	55	99	47	40	134	1.5	55
12	79	M	CAD, CABG, AF	AVB, SSS, AF	45	92	126	NS	0.6	60	55	95.9	45	130	0.8	60
13	81	F	HTN	HVB	HVB	160	126	NS	1.4	55	43	100	HVB	126	2.1	60
14	71	M	CAD, CABG, MVR, AF	AVB, SSS	50	86	86	S	2.6	60	49	92.8	50	88	2.5	59
15	79	F	HTN, AF	SSS, AF	45	86	126	NS	2.5	60	100	3	45	126	4	55
16	63	F	HTN, AF, NICM, DM	AVN abl, AF	45	90	130	NS	1	25	54	100	45	134	2	55
17	63	M	HTN, AF, DM	SSS	50	96	136	NS	4	55	54	1	50	136	4.5	54
18	69	F	CAD, CABG, MVR, ICM	AVB	45	86	86	S	1.2	40	36	100	45	90	4.5	50
19	85	M	HTN	AVB	40	102	132	NS	4.3	55	96	100	40	132	5	60
20	68	M	AF, NICM	SSS, AF	45	80	120	NS	1.2	45	57	3	45	124	0.8	55
Mean	**74.5**				**44**	**102.7**	**117.3**		**1.95**	**49.7**	**70.3**	**76.8**	**45**	**118.2**	**2.49**	**55.1**

Vijayaraman P, PACE. 2017;40:883-891.

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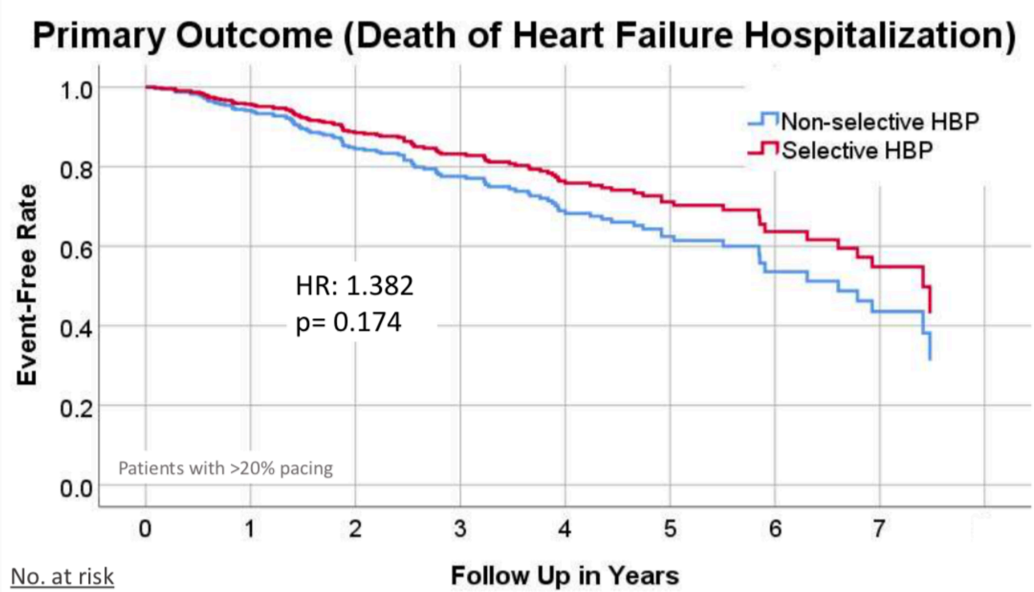
S-HBP vs. NS-HBP



No. at risk

NS-HBP	232	208	140	105	73	41	15	11
S-HBP	118	103	60	40	28	16	6	5

N = 640

Beer, J Am Coll Cardiol EP. 2019;5:766-74.

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2018 ACC/AHA/HRS Guideline on the Evaluation and Management of Patients With Bradycardia and Cardiac Conduction Delay

A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society

Fred M. Kusumoto, Mark H. Schoenfeld, Coletta Barrett, James R. Edgerton, Kenneth A. Ellenbogen, Michael R. Gold, Nora F. Goldschlager, Robert M. Hamilton, José A. Joglar, Robert J. Kim, Richard Lee, Joseph E. Marine, Christopher J. McLeod, Keith R. Oken, Kristen K. Patton, Cara N. Pellegrini, Kimberly A. Selzman, Annemarie Thompson and Paul D. Varosy

IIa	B-R[SR]	4. In patients with atrioventricular block who have an indication for permanent pacing with a LVEF between 36% and 50% and are expected to require ventricular pacing more than 40% of the time, it is reasonable to choose pacing methods that maintain physiologic ventricular activation (e.g., cardiac resynchronization therapy [CRT] or His bundle pacing) over right ventricular pacing (S6.4.4.1-7, S6.4.4.1-11–S6.4.4.1-19).

IIb	B-R[SR]	6. In patients with atrioventricular block at the level of the atrioventricular node who have an indication for permanent pacing, His bundle pacing may be considered to maintain physiologic ventricular activation (S6.4.4.1-19, S6.4.4.1-22–S6.4.4.1-25).

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What about patients with His-Purkinje Disease?

HBP in the presence of His-Purkinje Disease

- HBP can be successfully employed in patients with infranodal disease
- If present, BBB may or may not correct
  - Potential for a greater variety of capture patterns
  - May see multiple capture thresholds

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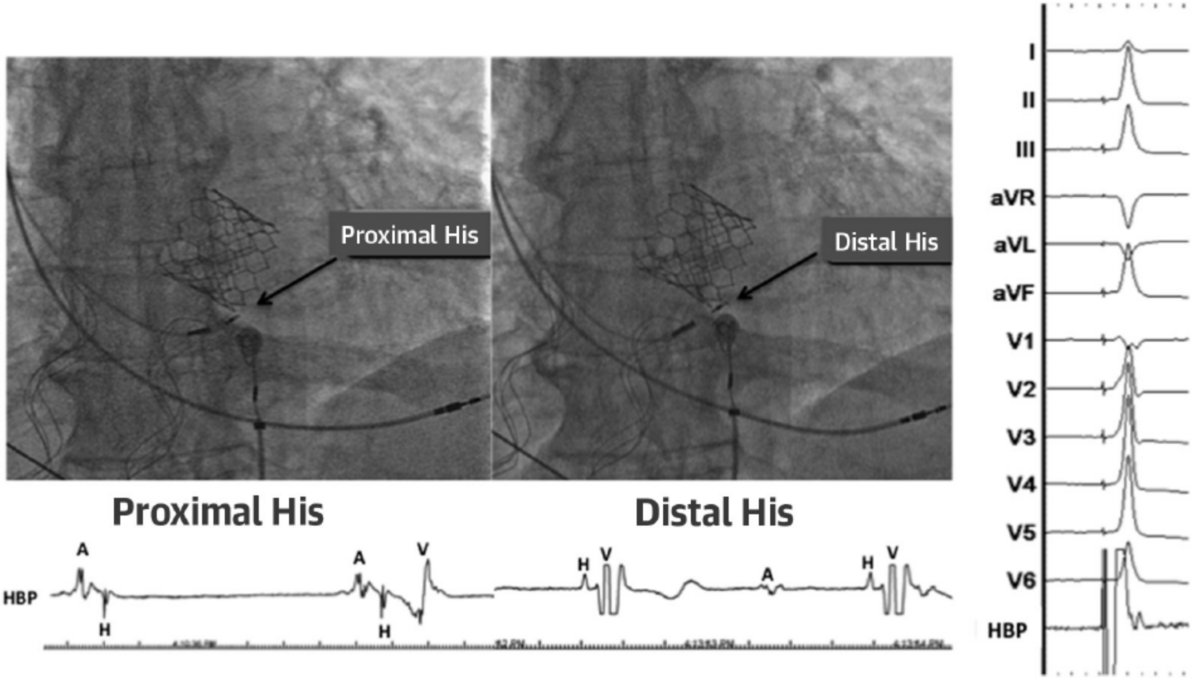
FIGURE 8 Mapping the Distal His Bundle in Infranodal AV Block Following Transcatheter Aortic Valve Replacement



Vijayaraman et al. JACC. 2018;72:927-47.

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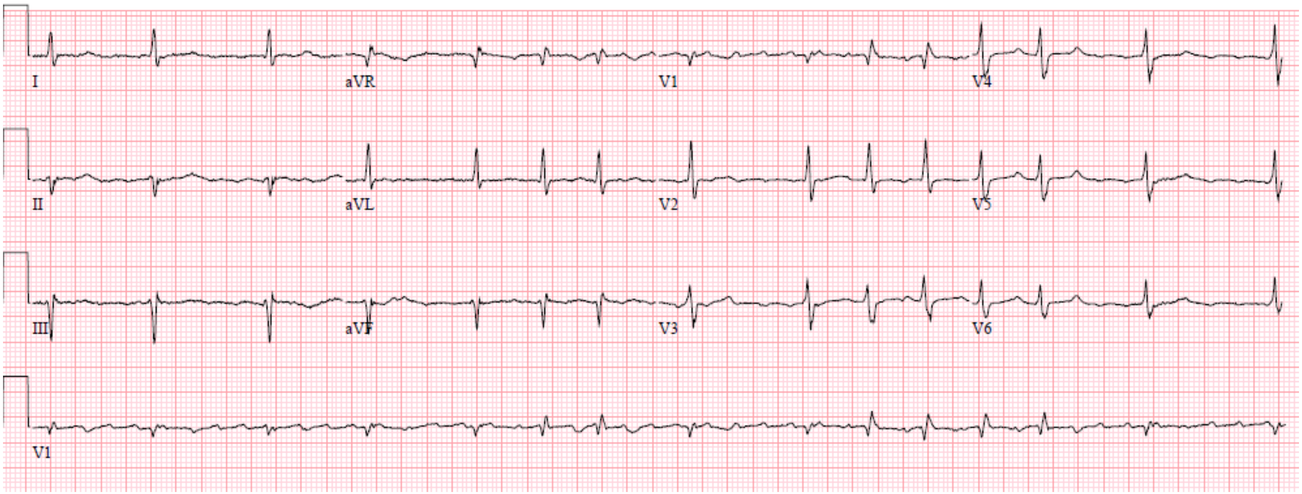
Case: 74M ECG 1/2016 pre-surgery



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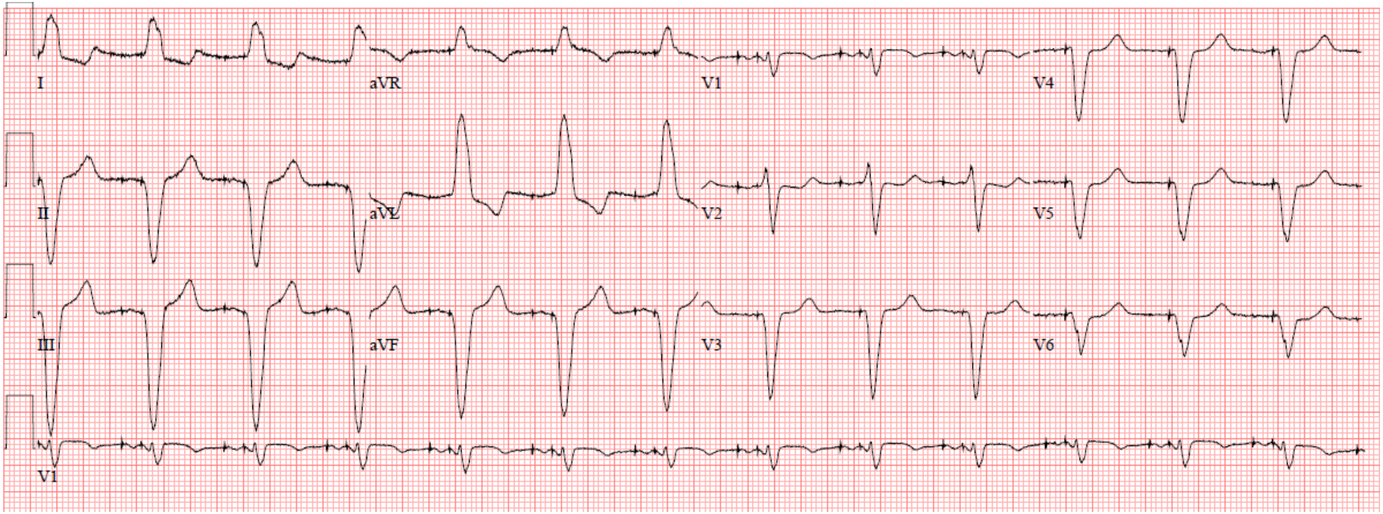
ECG following PM for post-AVR CHB



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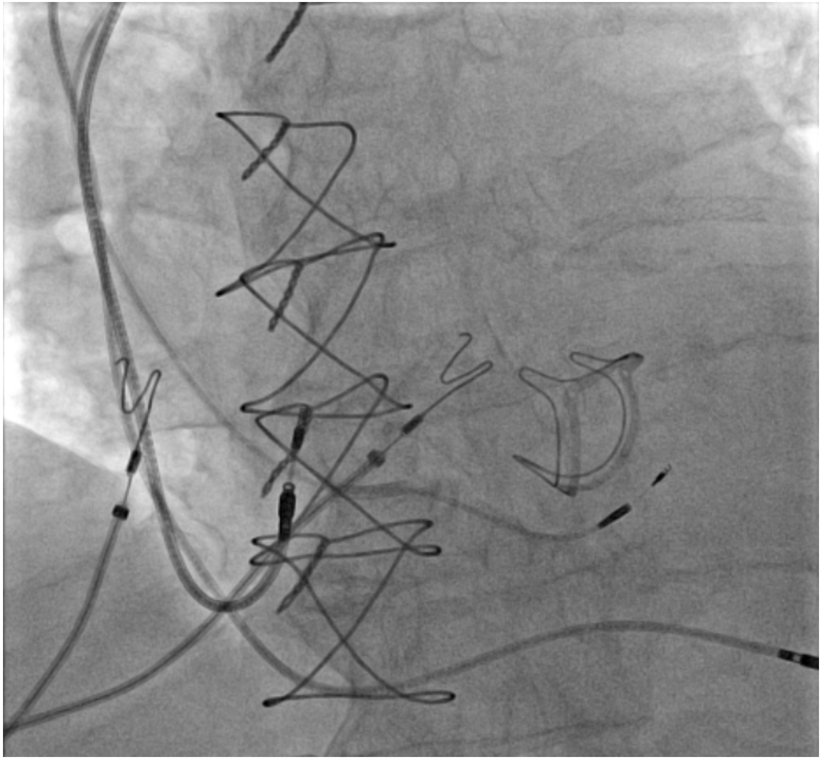

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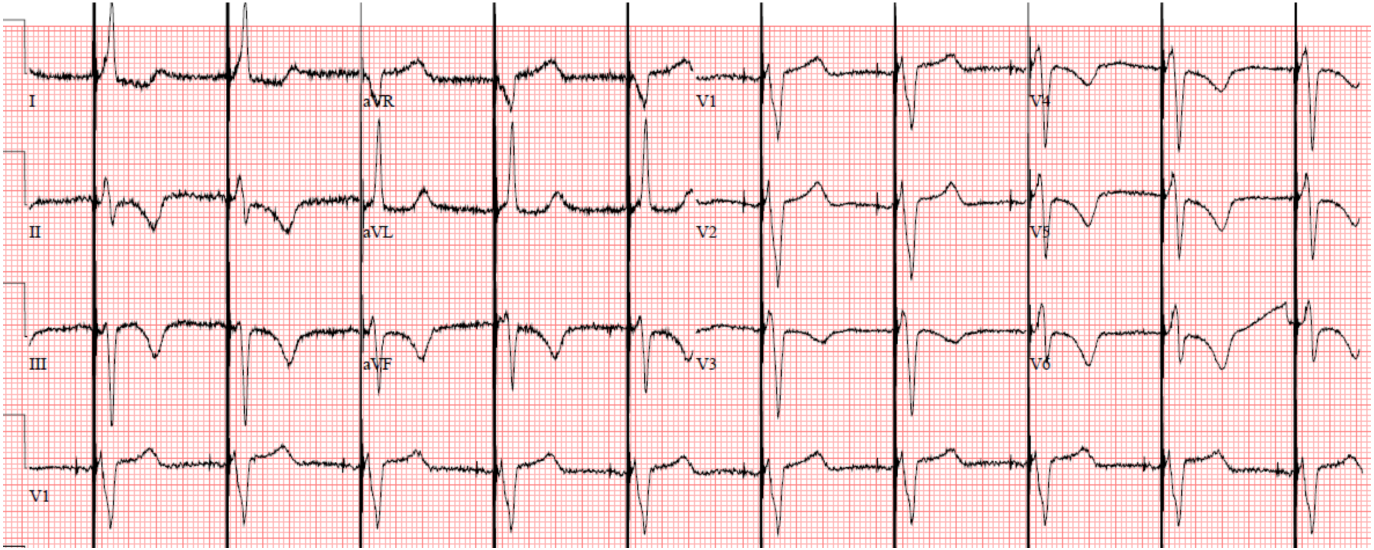
11/2017: NS-HBP



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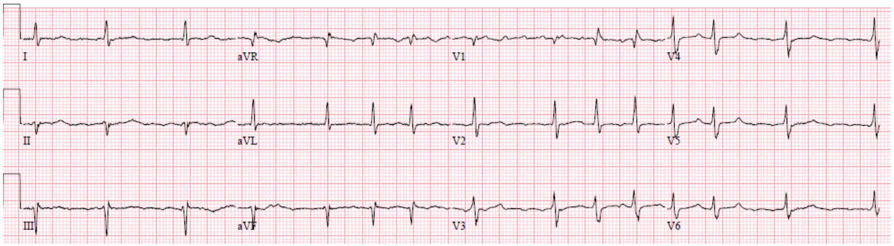
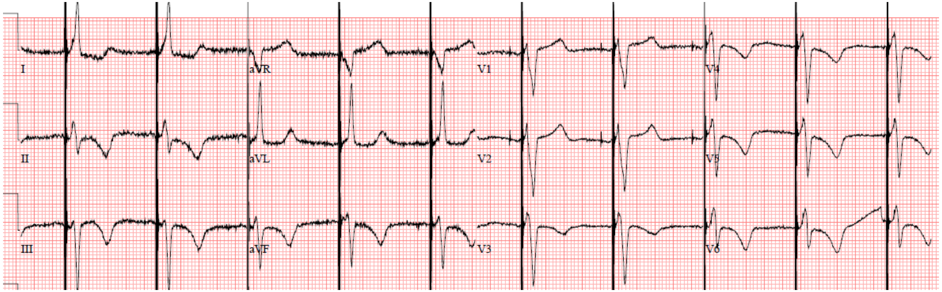
Pre-Heart Block vs. after "upgrade"





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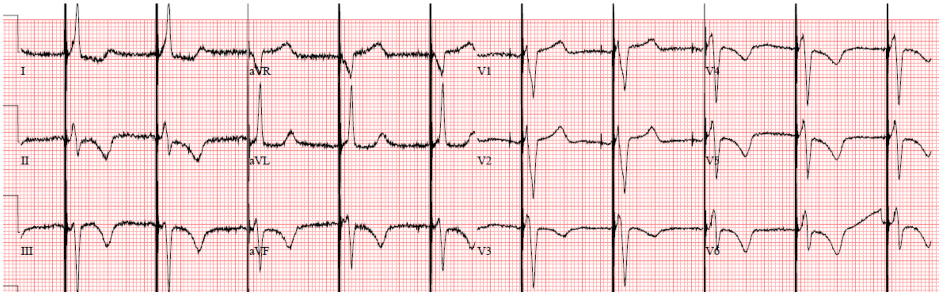
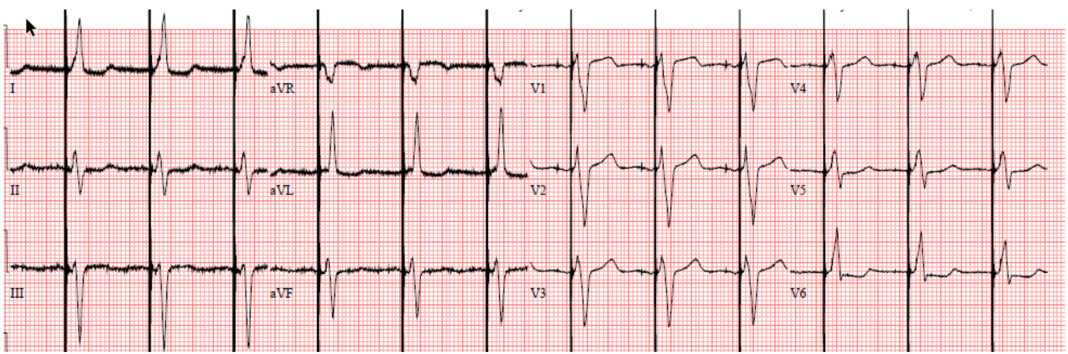
3 months later: EF 50-55%



Immediate post-im

3 months



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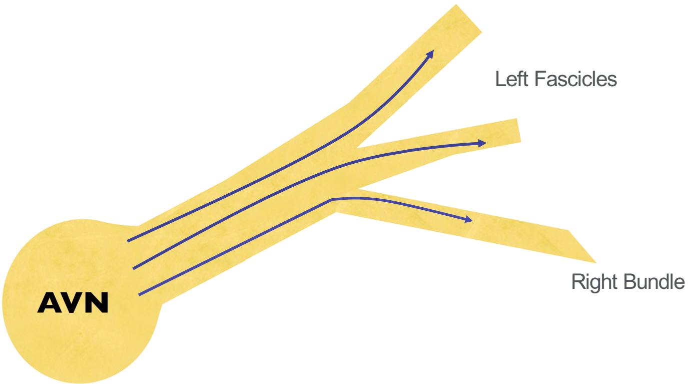
Longitudinal Dissociation of the His Bundle

- Discrete fibers predestined for the respective fascicles
- Poor transverse coupling
- Proximal disease can therefore result in BB pattern despite distal conducting tissue being normal



Adapted from N El-Sherif et al Circulation 1978;57;473-483

Longitudinal Dissociation of the His Bundle

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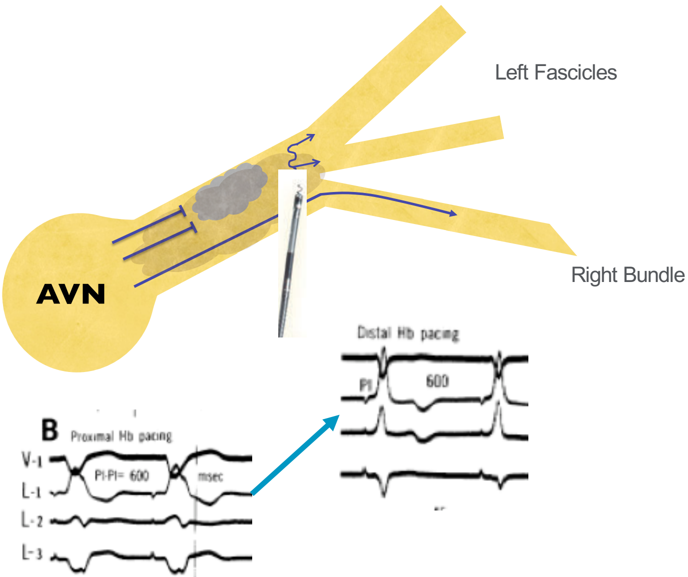

Adapted from N El-Sherif et al Circulation 1978;57;473-483

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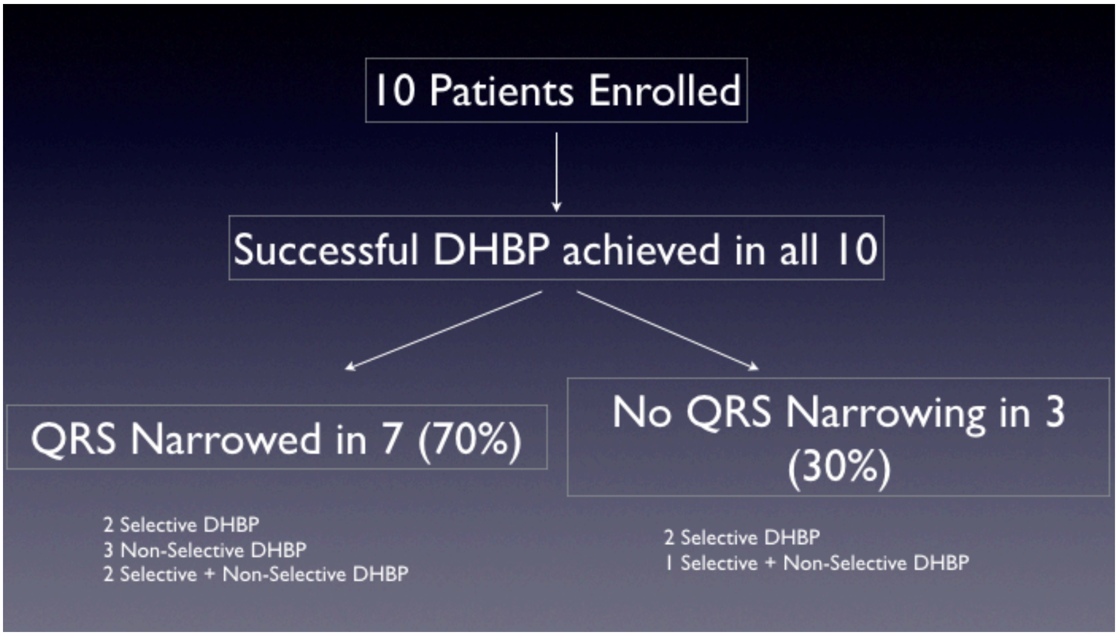
Electrical resynchronization induced by direct His-bundle pacing

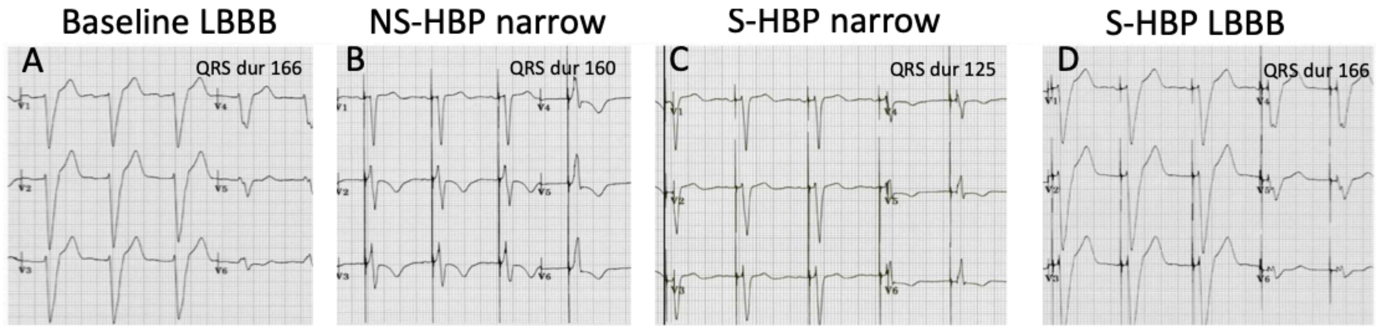
Daniel L. Lustgarten, MD, PhD,* Susan Calame, RN,* Eric M. Crespo, MD James Calame, RN,
Robert Lobel, MD, Peter S. Spector, MD*

*From the Department of Medicine at the University of Vermont School of Medicine and Fletcher Allen Health Care, Burlington, Vermont, and the *Cardiovascular Research Institute, Burlington, Vermont.*

(Heart Rhythm 2010;7:15–21)



Correction of LBBB



Decreasing Pacing Output →

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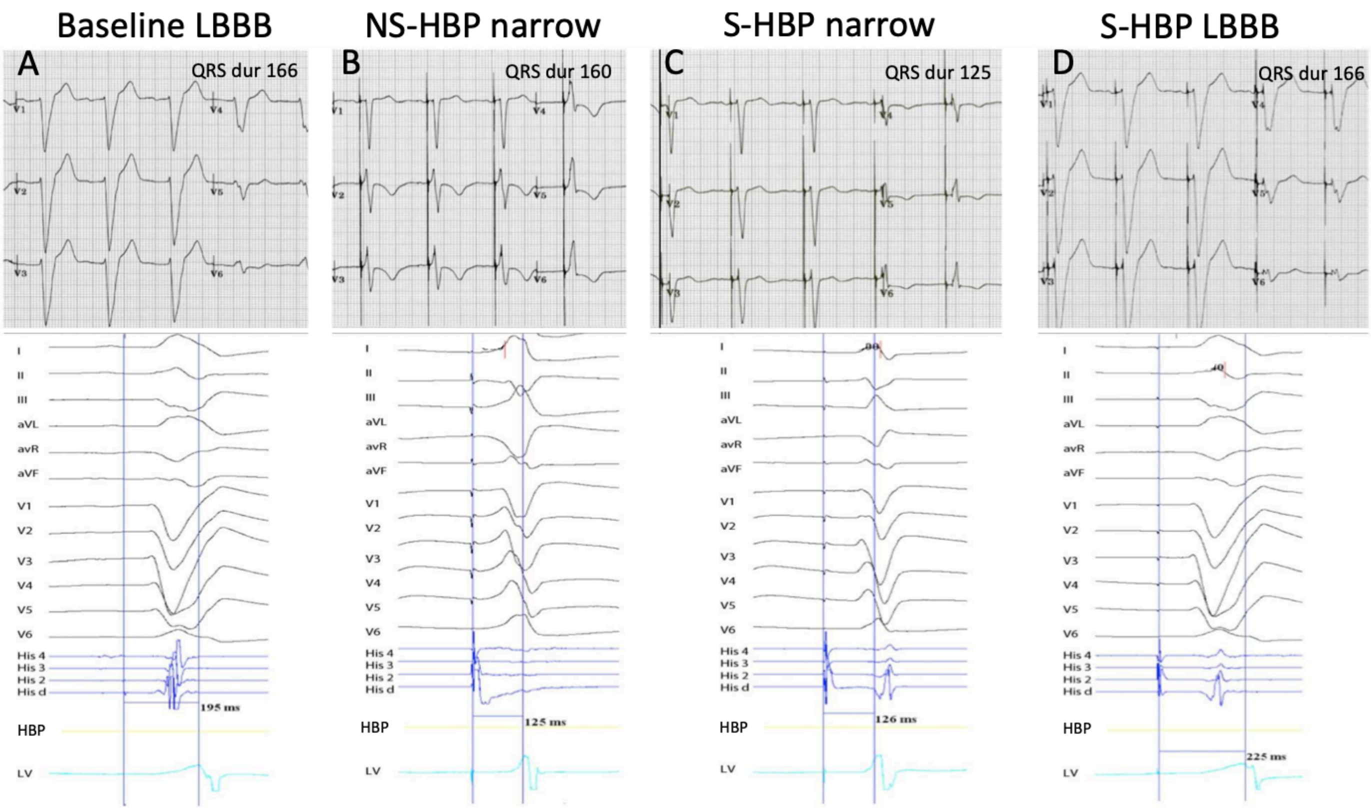
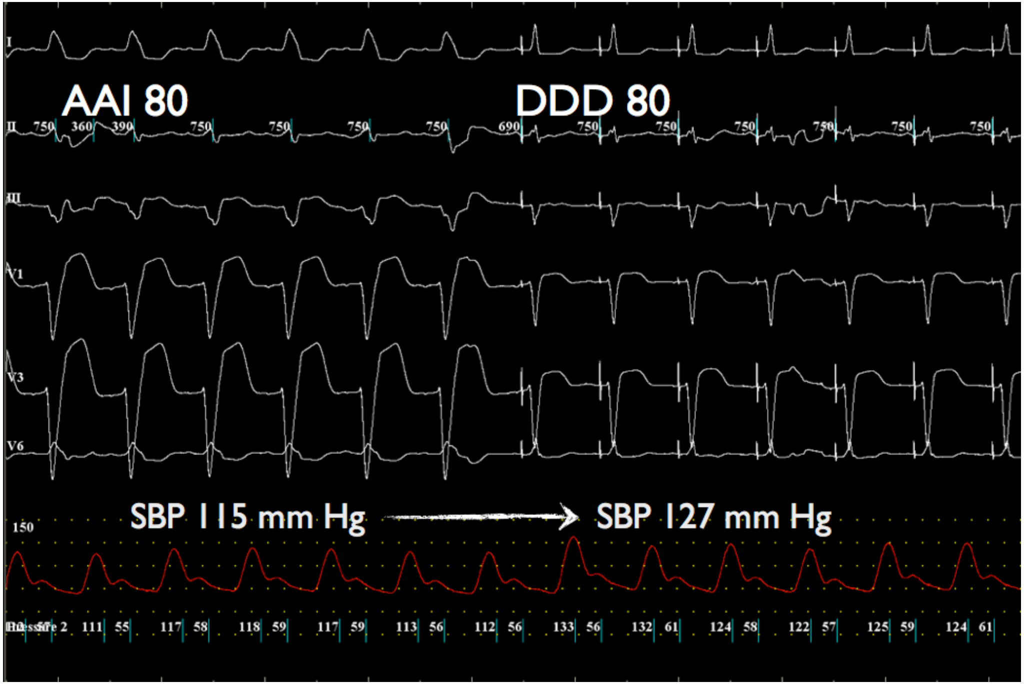
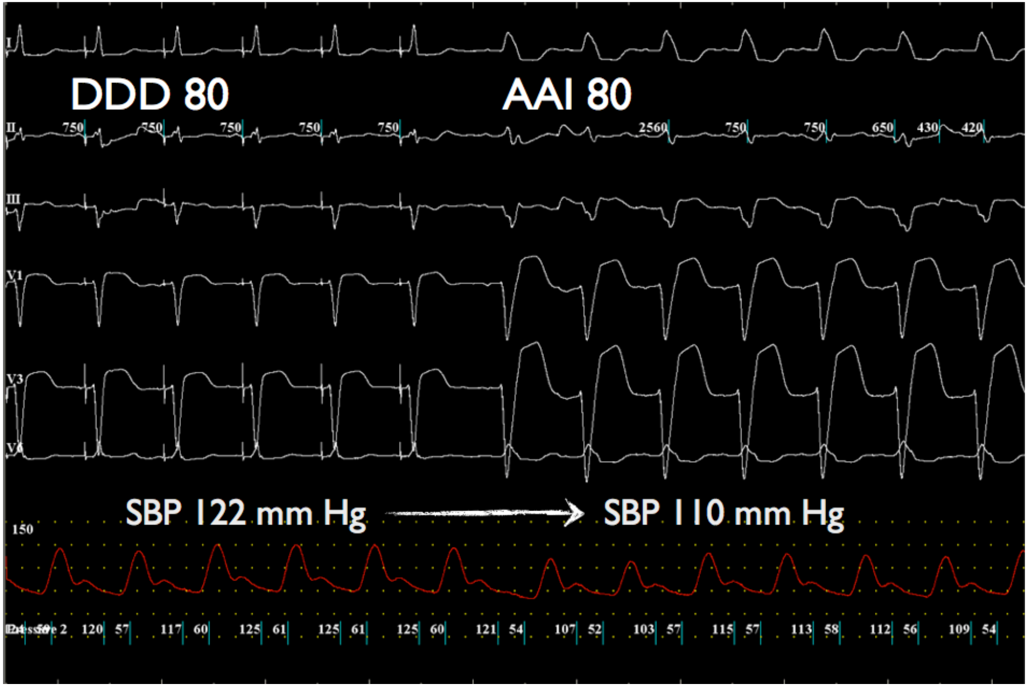
Correction of LBBB



Hemodynamic Response



Hemodynamic Response



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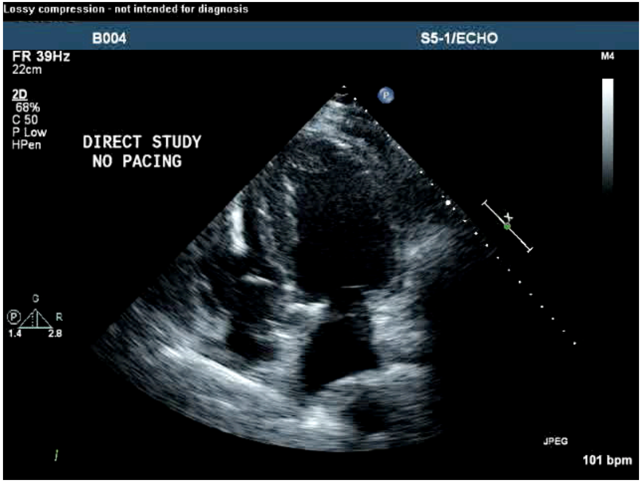

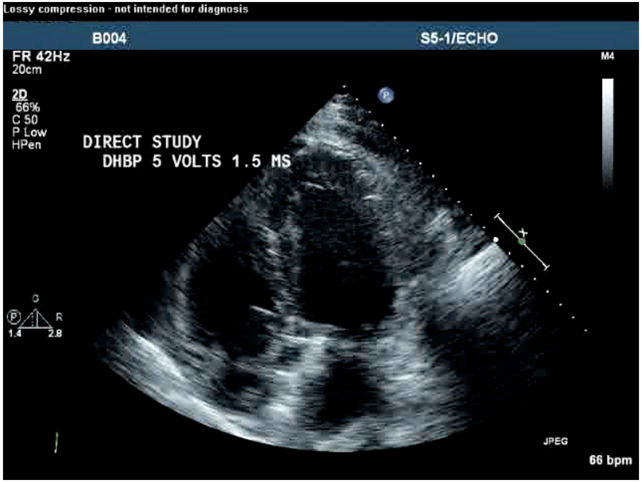

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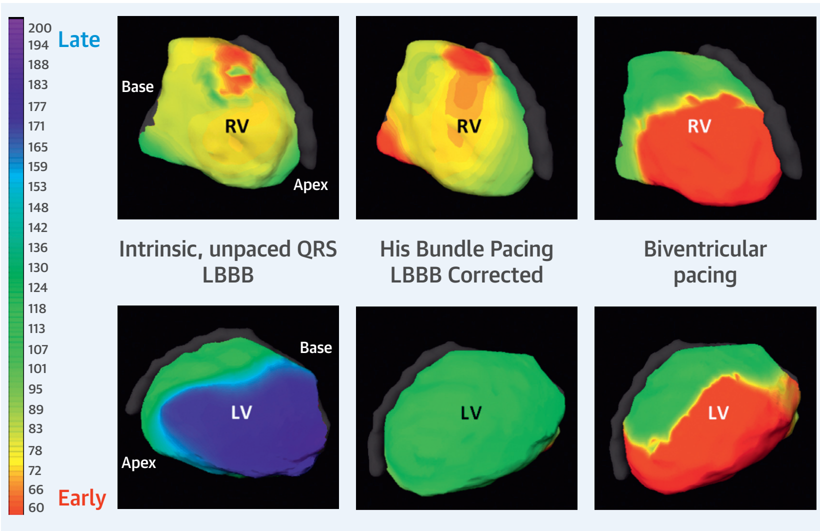

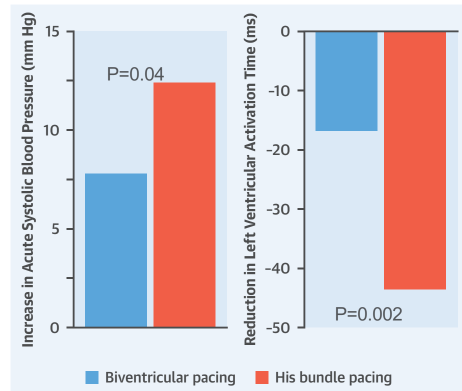

Arnold, A.D. et al. J Am Coll Cardiol. 2018;72(24):3112-22.

Growing Data on HBP for CRT

Study	Design	Comments	N	QRS Narrowing	Outcome
Lustgarten 2010	Prospective	Temporary HBP in patients undergoing CRT implant	10	70%	HBP implant faster than LV lead (16 min vs. 42 min)
Barba-Pichado 2013	Prospective	HBP attempted in pts with failed CRT implant	16	56%	Improvements in NYHA class, LVEF, and LV dimensions
Lustgarten 2015	Prospective cross-over	Both HBP and LV leads implanted	29	72%	Comparable improvement in NYHA class, LVEF, 6 min walk when comparing HBP to CRT
Ajijola 2015	Prospective	HBP attempted in pts with failed CRT implant	13	92%	Improvements in LVEF and LV dimensions
Vijayaraman 2016	Prospective	Mixed group of failed CRT and primary HBP	32	91%	Improvements in NYHA class and LVEF
Ajijola 2017	Prospective	HBP in lieu of LV lead in patients indicated for CRT	21	76%	Improvement in NYHA class, LVEF, LV dimensions

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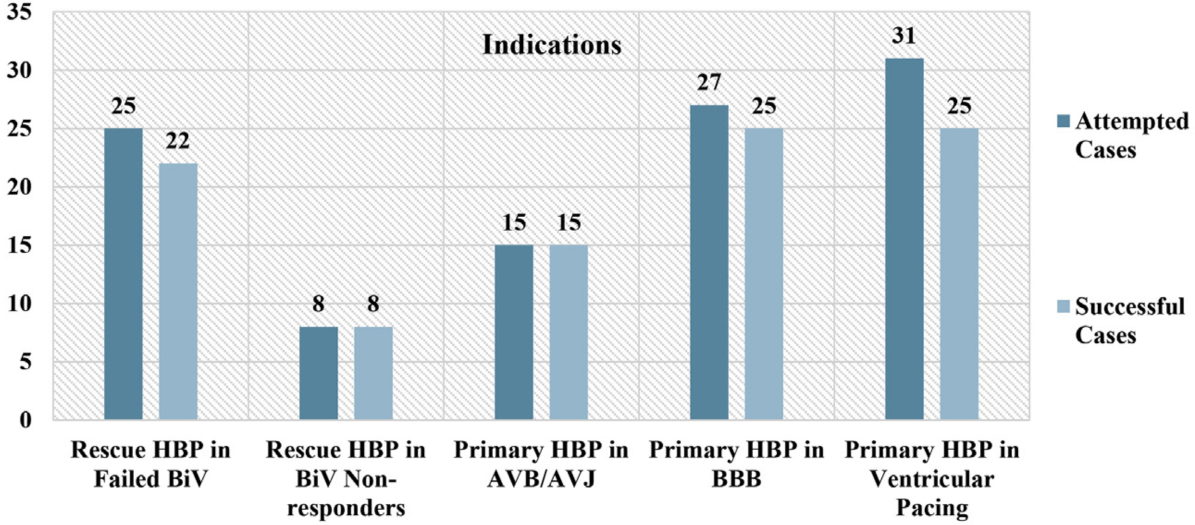
Permanent His-bundle pacing as an alternative to biventricular pacing for cardiac resynchronization therapy: A multicenter experience

Parikshit S. Sharma, MD, MPH, FACC,* Gopi Dandamudi, MD, FHRS,† Bengt Herweg, MD,‡
David Wilson, MD,‡ Rajeev Singh, MD,† Angela Naperkowski, RN, FHRS, CCDS, CEPS,§
Jayanthi N. Koneru, MBBS,¶ Kenneth A. Ellenbogen, MD, FACC, FHRS,¶
Pugazhendhi Vijayaraman, MD, FACC, FHRS§

- 5 centers
- Retrospective
- 2 Groups
  - Rescue HBP: (failed LV lead or BiV non-responder)
  - Primary HBP for CRT-eligible patients
    - Instead of LV lead
    - Expected frequent RV pacing (AV block or AV node ablation)
    - Upgrade due to frequent RV pacing
- Median f/u 14 months

Sharma P,, et al. Heart Rhythm. 2018;15:413-420.



90% successful HBP

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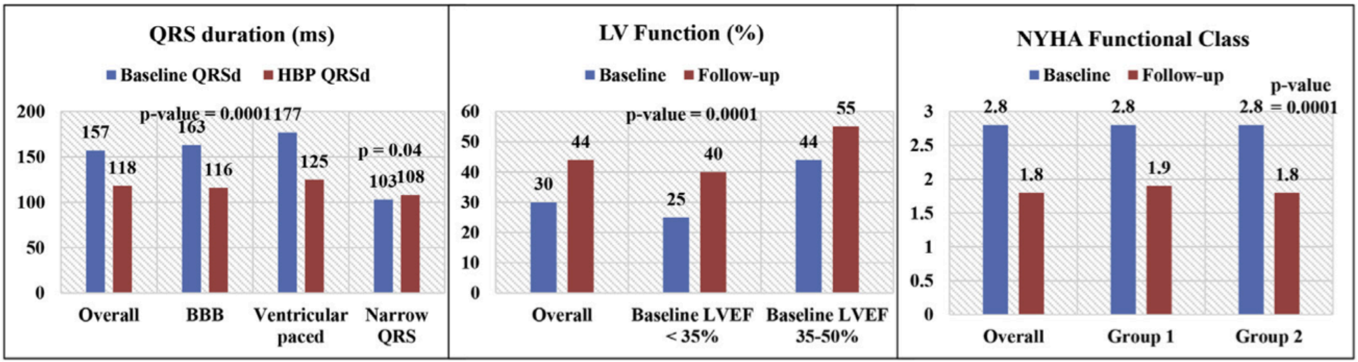

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Characteristic	Baseline	Follow-up	*P* value
R-wave amplitude (mV)	4 ± 3.4	5.4 ± 4.9	.03
Impedance (ohms)	483 ± 153	413 ± 109	.0001
His capture Threshold (V @ 1 ms)	1.4 ± 0.9	1.72 ± 1.4	.17
BBB recruitment threshold	2 ± 1.2	2.2 ± 1.7	.63

Complication	
Pneumothorax (n, %)	0
Pericardial effusion (n, %)	0
Increase in capture threshold (n, %)	7/95 (7.4%)
Loss of BBB recruitment (n, %)	3/44 (7%)
Device infection	1

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His-SYNC: His Bundle Pacing vs Coronary Sinus Pacing for CRT

- Prospective, single-blinded RCT
- HBP vs BiV in patients with standard CRT indication
- 5/2016 – 6/2018; 7 centers
- Outcomes:
  - change in QRS duration
  - improvement in LVEF at 6 months
  - Time to CV hospitalization or death at 12 months

- Cross-over if:
  - HBP to BiV: if HPB did not narrow QRS by >20% or if HBP threshold >5V
  - BiV to HBP: if LV lead could not be placed

Upadhyay GA, et al. J Am Coll Cardiol. 2019.

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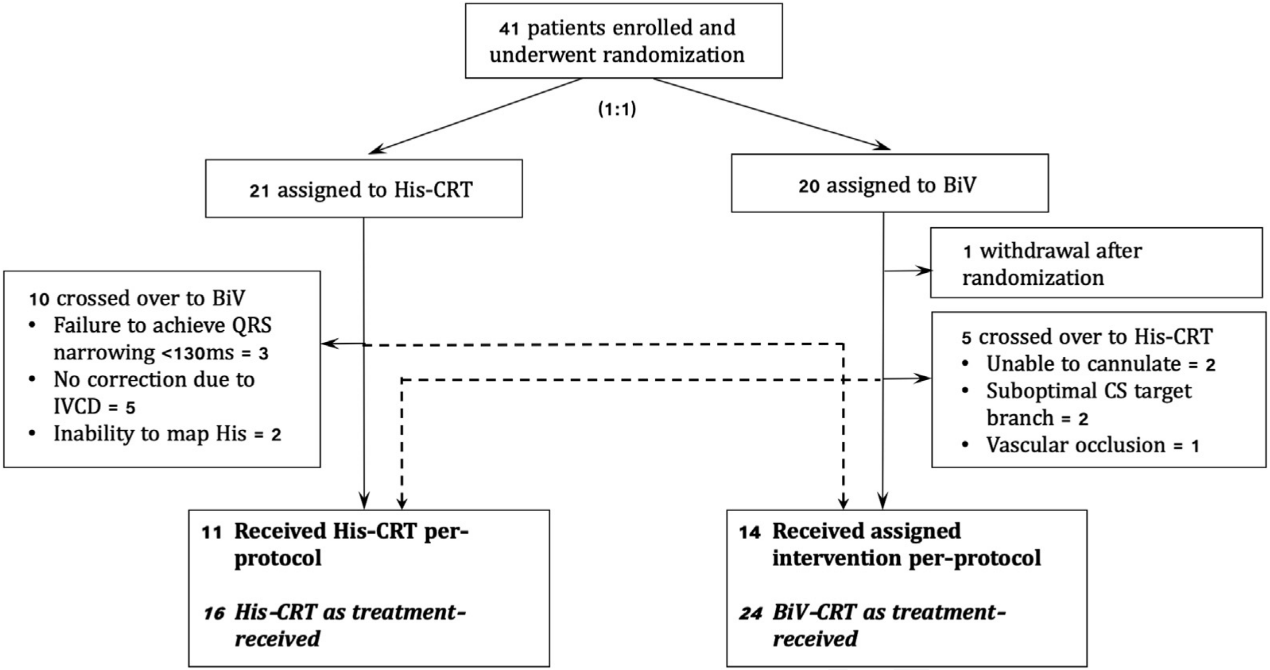
His-SYNC: His Bundle Pacing vs Coronary Sinus Pacing for CRT



Upadhyay GA, et al. Heart Rhythm. 2019.In press

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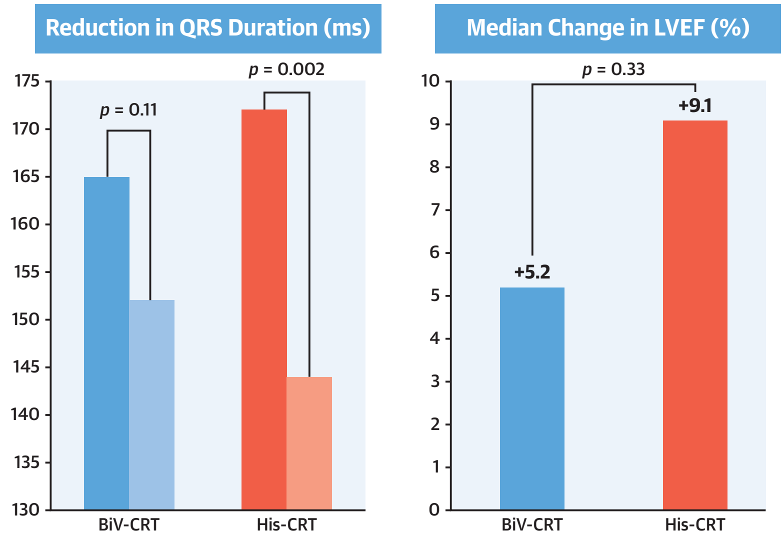
His-Sync: ITT analysis

- Greater QRS narrowing with HBP
- No significant difference in LVEF
- No difference in event rates at 12 months



Upadhyay GA, et al. J Am Coll Cardiol. 2019.

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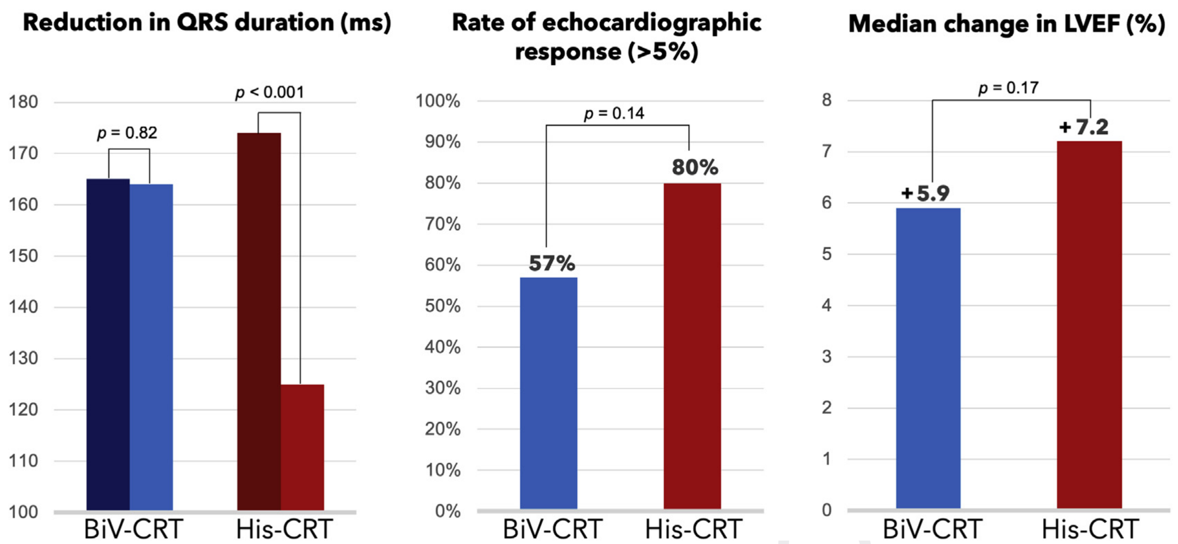
His-SYNC: On Treatment Analysis



No difference in CV hospitalization of mortality at 12 months

Upadhyay GA, et al. Heart Rhythm. 2019.In press

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Table 2 Device parameters in follow-up by on-treatment group (His-CRT or BiV)

Parameter	His-CRT (n = 16)	BiV (n = 24)	*P* value
Implant measurements			
RA lead sensing (mV)	2.00 (1.50–3.80)	1.75 (1.25–3.50)	.457
RA lead capture threshold (V)	0.75 (0.60–1.25)	0.70 (0.50–1.00)	.134
RA lead pulse width (ms)	0.40 (0.40–0.50)	0.50 (0.40–0.50)	.384
RA lead impedance (ohms)	475 (399–726)	494 (399–600)	.641
RV lead sensing (mV)	10.25 (9.40–14.80)	12.00 (7.30–15.10)	.910
RV lead threshold (V)	0.50 (0.50–0.75)	0.50 (0.50–1.00)	.241
RV lead pulse width (ms)	0.40 (0.40–0.50)	0.40 (0.40–0.50)	.746
RV lead impedance (ohms)	513 (475–608)	492.50 (428–555)	.334
His or LV threshold (V)*	**2.75 (1.25–3.38)**	**0.85 (0.73–1.31)**	**.002**
His or LV pulse width (ms)	**1.00 (1.00–1.00)**	**0.50 (0.40–0.65)**	**<.001**
His or LV impedance (ohms)	**433 (340–481)**	**540 (497–680)**	**.001**
6-Month follow-up			
RA lead sensing (mV)	3.55 (2.50–4.60)	2.40 (1.95–3.55)	.111
RA lead capture threshold (V)	0.75 (0.50–0.80)	0.66 (0.55–0.81)	.721
RA lead pulse width (ms)	0.40 (0.40–0.40)	0.40 (0.40–0.40)	.684
RA lead impedance (ohms)	485 (456–513)	456 (380–513)	.345
RV lead sensing (mV)	13.65 (9.13–16.88)	12.50 (11.30–20.00)	.275
RV lead threshold (V)	0.50 (0.50–0.75)	0.75 (0.50–1.00)	.184
RV lead pulse width (ms)	0.40 (0.40–0.40)	0.40 (0.40–0.40)	.647
RV lead impedance (ohms)	456 (399–551)	428 (380–513)	.361
His or LV threshold (V)*	**2.00 (1.00–3.25)**	**0.94 (0.75–1.25)**	**.004**
His or LV pulse width (ms)	**1.00 (1.00–1.00)**	**0.40 (0.40–0.50)**	**<.001**
His or LV impedance (ohms)	**295 (284–390)**	**615 (456–703)**	**<.001**

BiV = biventricular pacing; CRT = cardiac resynchronization therapy; LV = left ventricular; RA = right atrial; RV = right ventricular.
*Threshold for QRS correction is reported for His bundle pacing.

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His-SYNC: Bottom Line

- In an unselected CRT-eligible population, HBP (when it can be achieved) appears to result in greater electrical resynchronization and a trend towards greater echo response.

- Based on these results, HBP is not a suitable first-line therapy in this population.

- Further investigation is required utilizing more refined tools and with different patient selection criteria.

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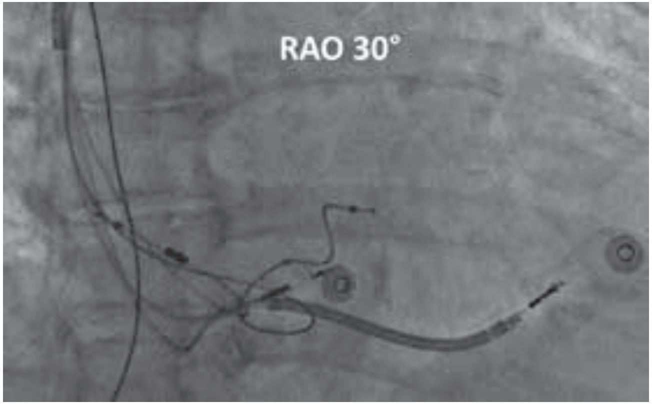
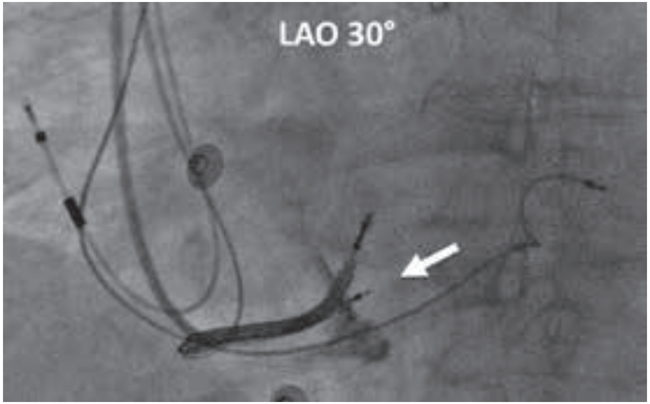
Future Direction: LBB Pacing?





Vijayaraman.. J Innovations in Cardiac Rhythm Management. 2019. 10: 3668-3673

Conclusions

- HBP is the MOST physiologic form of ventricular pacing
- It is not associated with pacing-induced CM
- There is a growing body of evidence that supports the use of HBP as a viable alternative to traditional forms of ventricular pacing
- HBP may offer an alternative form of CRT and can likely be considered a bail-out in patients with failed LV implant
- Technical challenges remain and more research is needed

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Questions?