RHNe

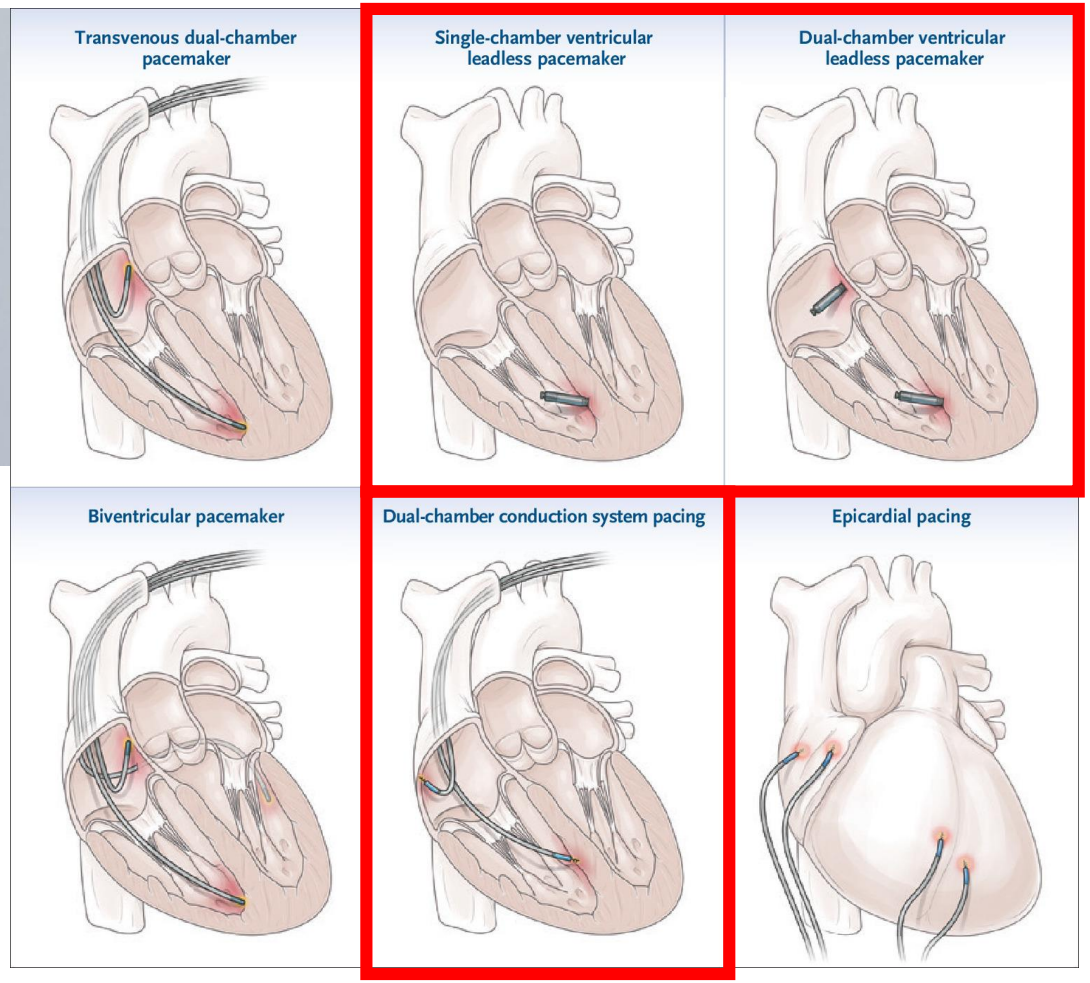
Réseau Hospitalier Neuchâtelois

Les nouvelles techniques de stimulation cardiaque : du pacemaker sans sonde à la stimulation du système de conduction électrique cardiaque

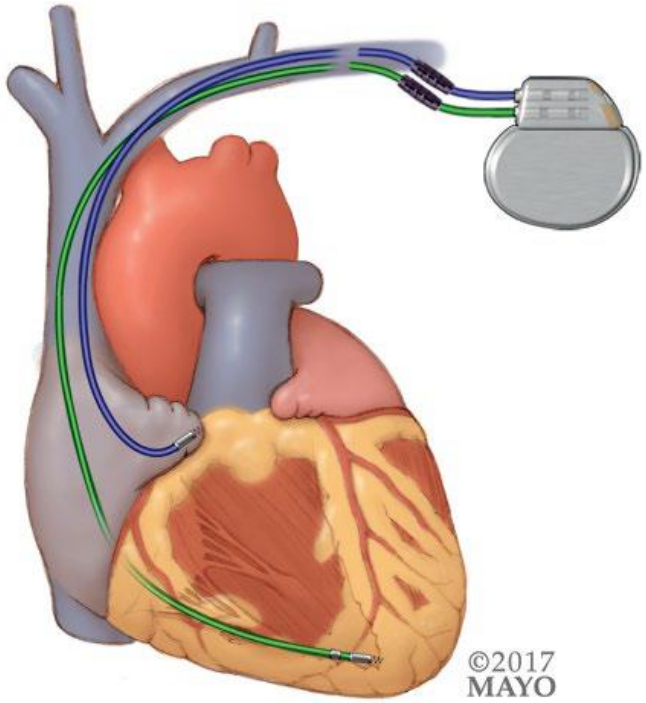
Dr. méd. Aruran Baskaralingam

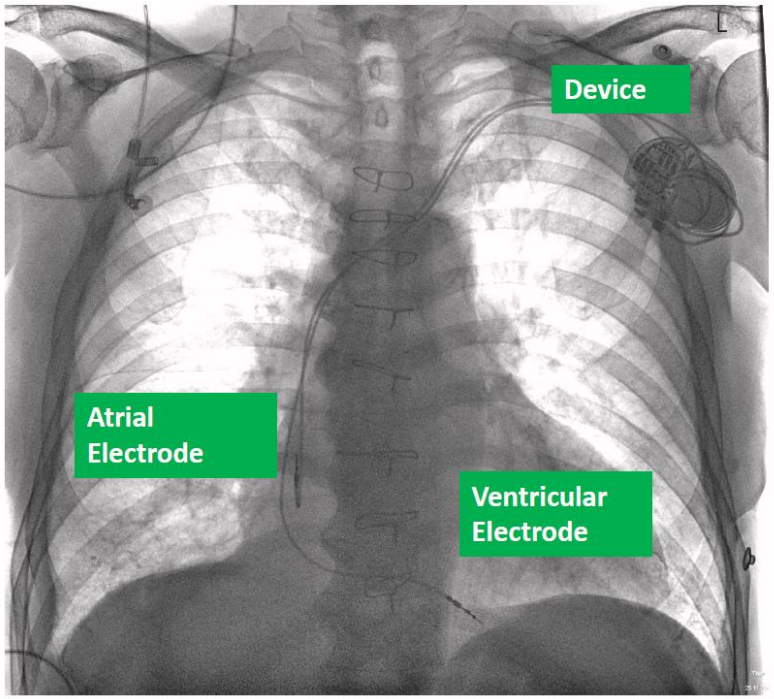
FMH cardiologie et médecine interne

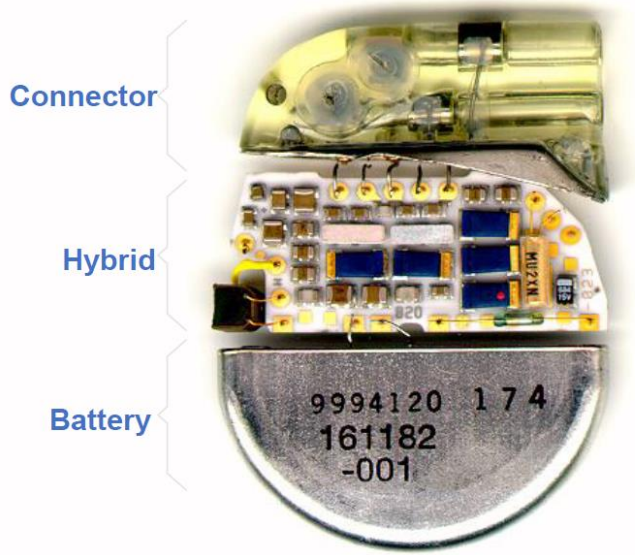
Type de électro-stimulation cardiaque disponible en Suisse



Pacemaker dit conventionnel (right ventricular pacing, RVP)

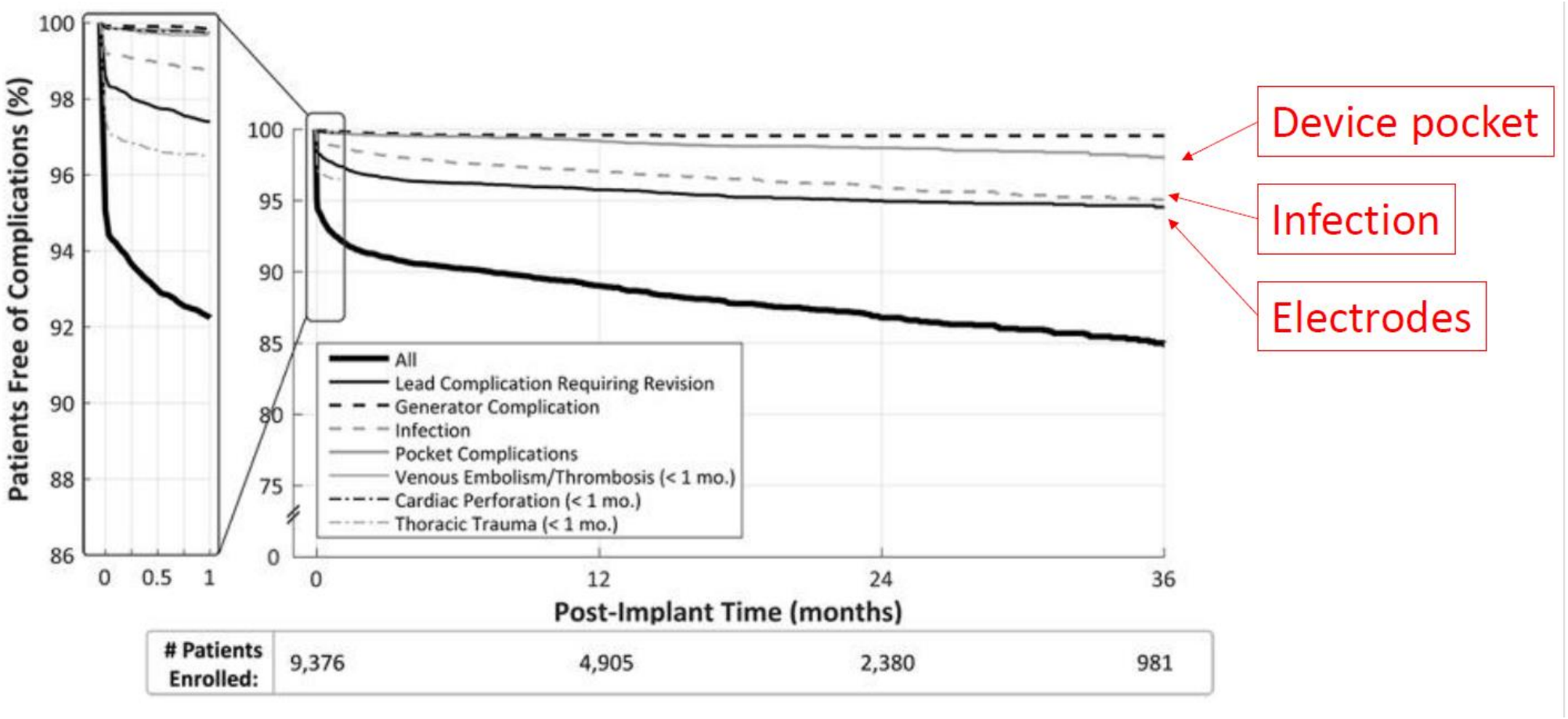






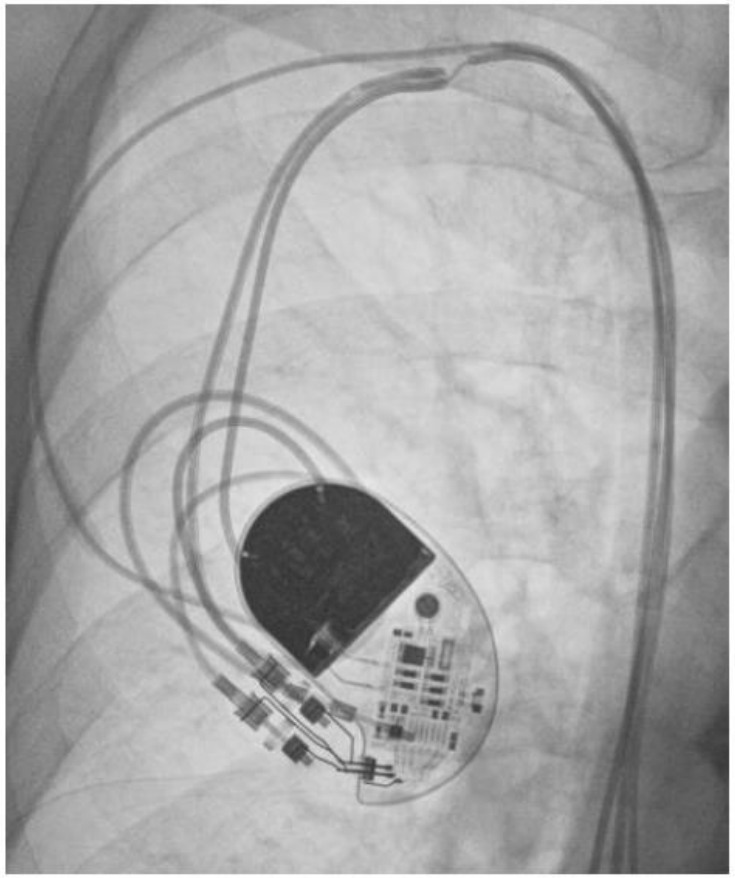
Courtesy of Dr D.Hofer

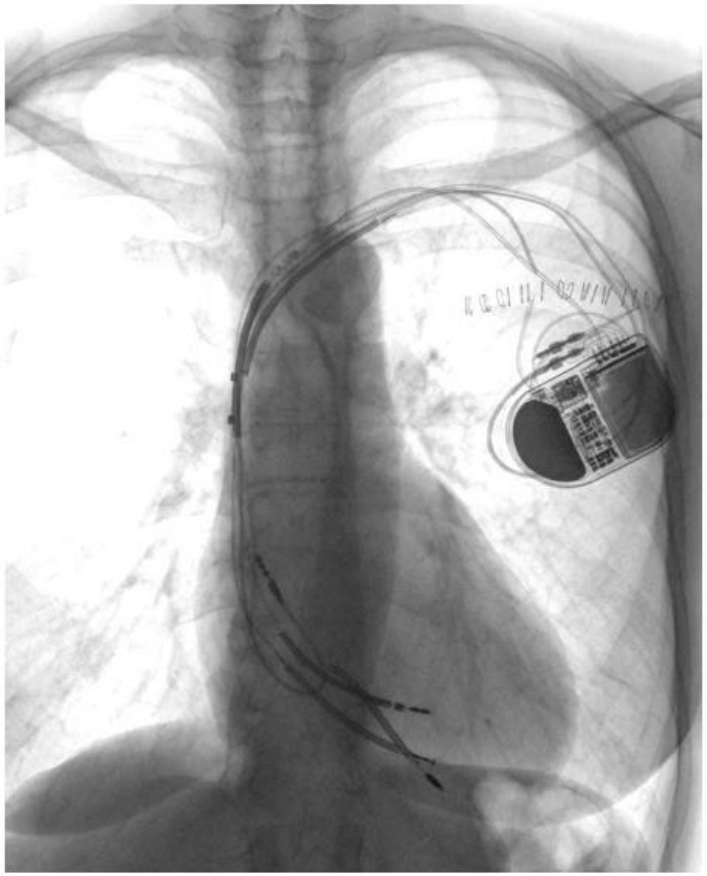
Complications au long cours d'un pacemaker « conventionnel »



Complications and Health Care Costs Associated with Transvenous Cardiac Pacemakers, Cantillon et al. JACC Clinical EP, 2017

Pas anodin…





Nomenclature NBG

Table 6.1 Revised NASPE/BPEG generic code for bradycardia, adaptive-rate, and multisite pacing

Position				
I	*II*	*III*	*IV*	*V*
Chamber(s) paced	*Chamber(s) sensed*	*Response to sensing*	*Rate modulation*	*Multisite pacing*
O = None	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	T = Triggered	R = Rate modulation	A = Atrium
V = Ventricle	V = Ventricle	I = Inhibited		V = Ventricle
D = Dual (A + V)	D = Dual (A + V)	D = Dual (T + I)		D = Dual (A+V)

Ellenbogen, K. A., & Kaszala, K. (Éds.). (2020). *Cardiac Pacing and ICDs* (7e éd.). Wiley-Blackwell. ISBN 978-1-119-57833-8.

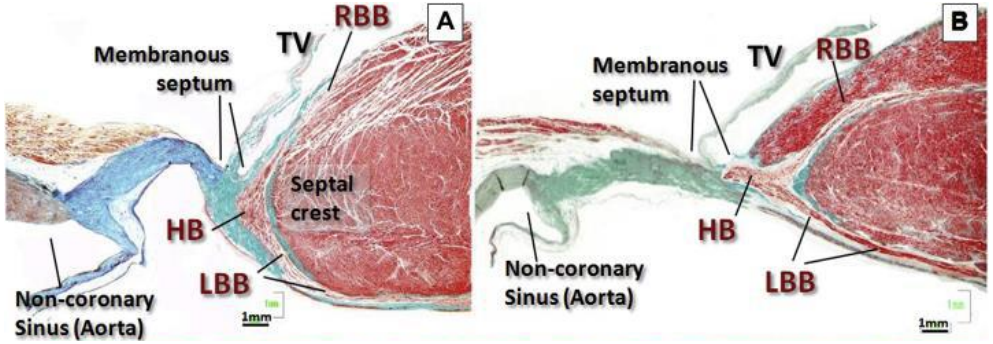
Mode de stimulation : un bref rappel

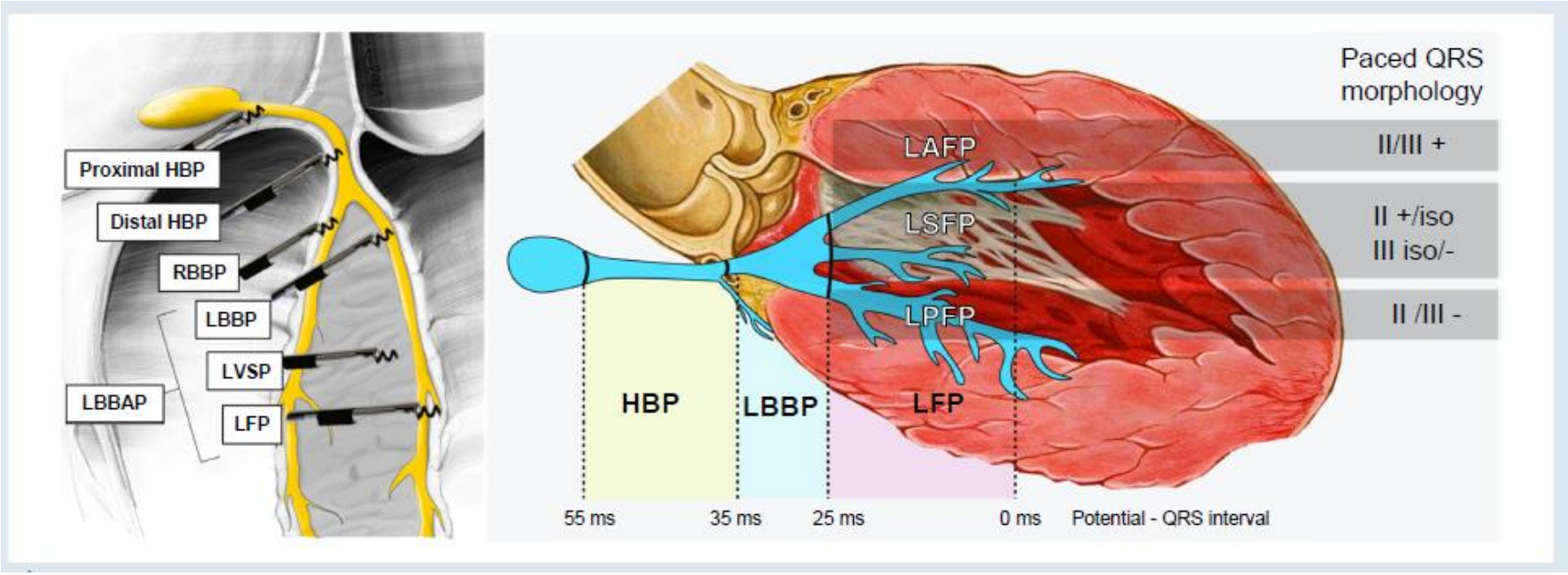
Table 6.2 Indications, advantages, and disadvantages of commonly used pacing modes

Pacing mode	*Indication/advantages*	*Disadvantages*
Asynchronous pacing (AOO, VOO, DOO)	Pacemaker-dependent patients exposed to noise (e.g. electrocautery during surgery) Avoids oversensing and asystole	Pacing regardless of intrinsic events Potential risk for proarrhythmia
Single-chamber inhibited pacing (AAI, VVI)	AAI: sick sinus syndrome with intact AV node; preserves AV synchrony VVI: atrial fibrillation with slow VR and single-lead ICDs AAI/VVI require a single lead and increase battery longevity	AAI lacks ventricular pacing in the event of intermittent AV block VVI is associated with AV dyssynchrony (may manifest as pacemaker syndrome). VVI has a higher incidence of atrial arrhythmias [31]
Single-chamber triggered without inhibited pacing (AAT, VVT)	Historically used in pacemaker-dependent patients to assure pacing with lower probability of arrhythmia induction	Shortens battery life due to chronic pacing
DDD, DDDRV (CRT)	Preserves AV synchrony (less pacemaker syndrome) Low incidence of atrial arrhythmias and improved hemodynamics	Requires at least a two-chamber lead system and has a shorter battery longevity

Stimulation des voies de conductions électriques (conduction system pacing, CSP)

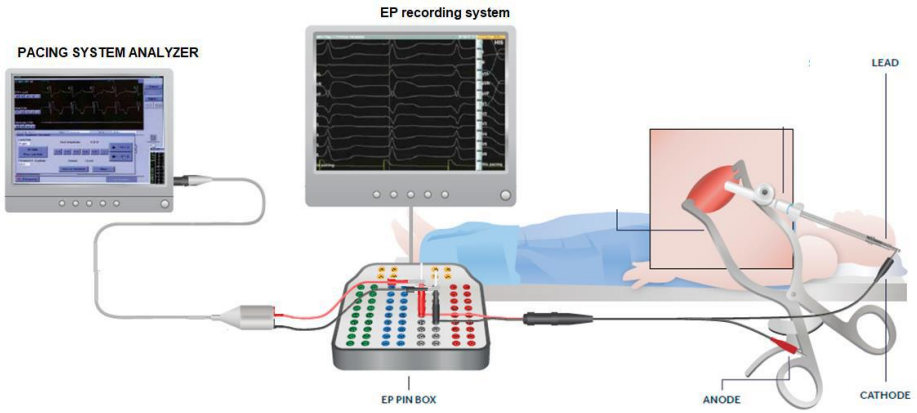
- faisceau de His (His bundle pacing, HBP)
- branche gauche du His (left bundle branche area pacing, LBBAP)



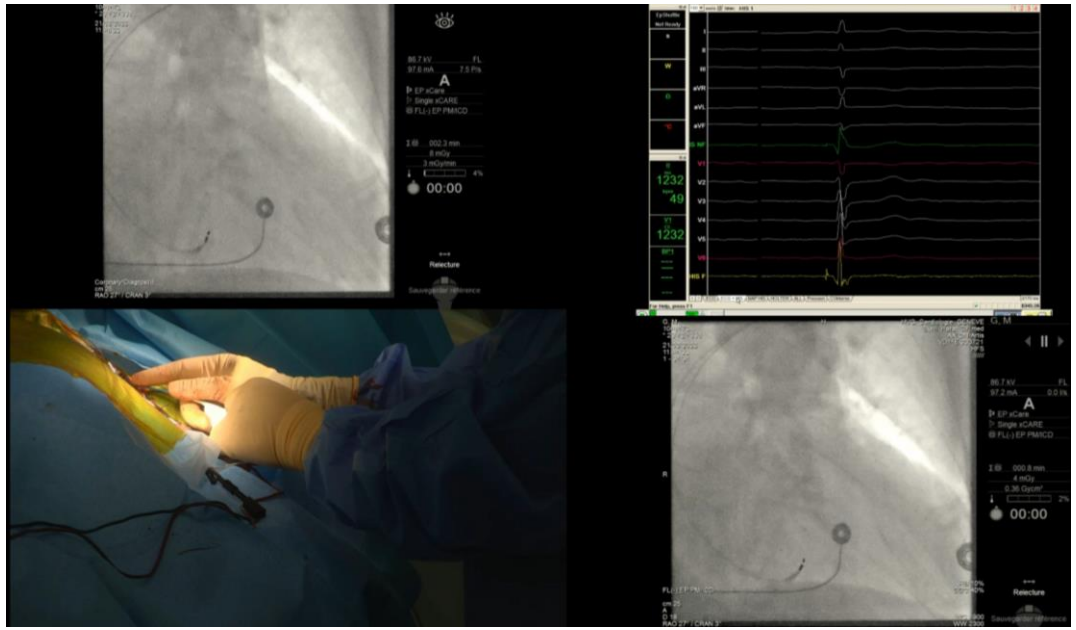


Michael Glikson et al European Society of Cardiology (ESC) clinical consensus statement on indications for conduction system pacing, with special contribution of the European Heart Rhythm Association of the ESC and endorsed by the Asia Pacific Heart Rhythm Society, the Canadian Heart Rhythm Society, the Heart Rhythm Society, and the Latin American Heart Rhythm Society, *EP Europace*, Volume 27, Issue 4, April 2025

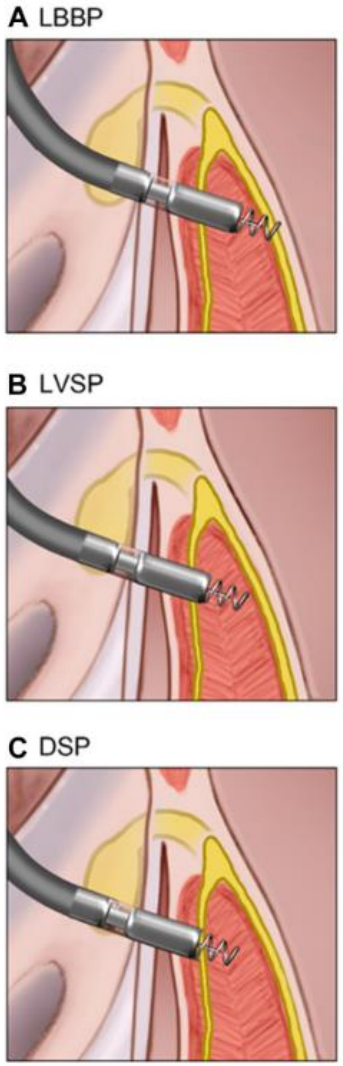
Déroulement de la procédure



Courtesy of Prof H.Burri



Vissage de la sonde avec stimulation unipolaire en continue



Endpoints électrocardiographique d'une stimulation type LBBAP

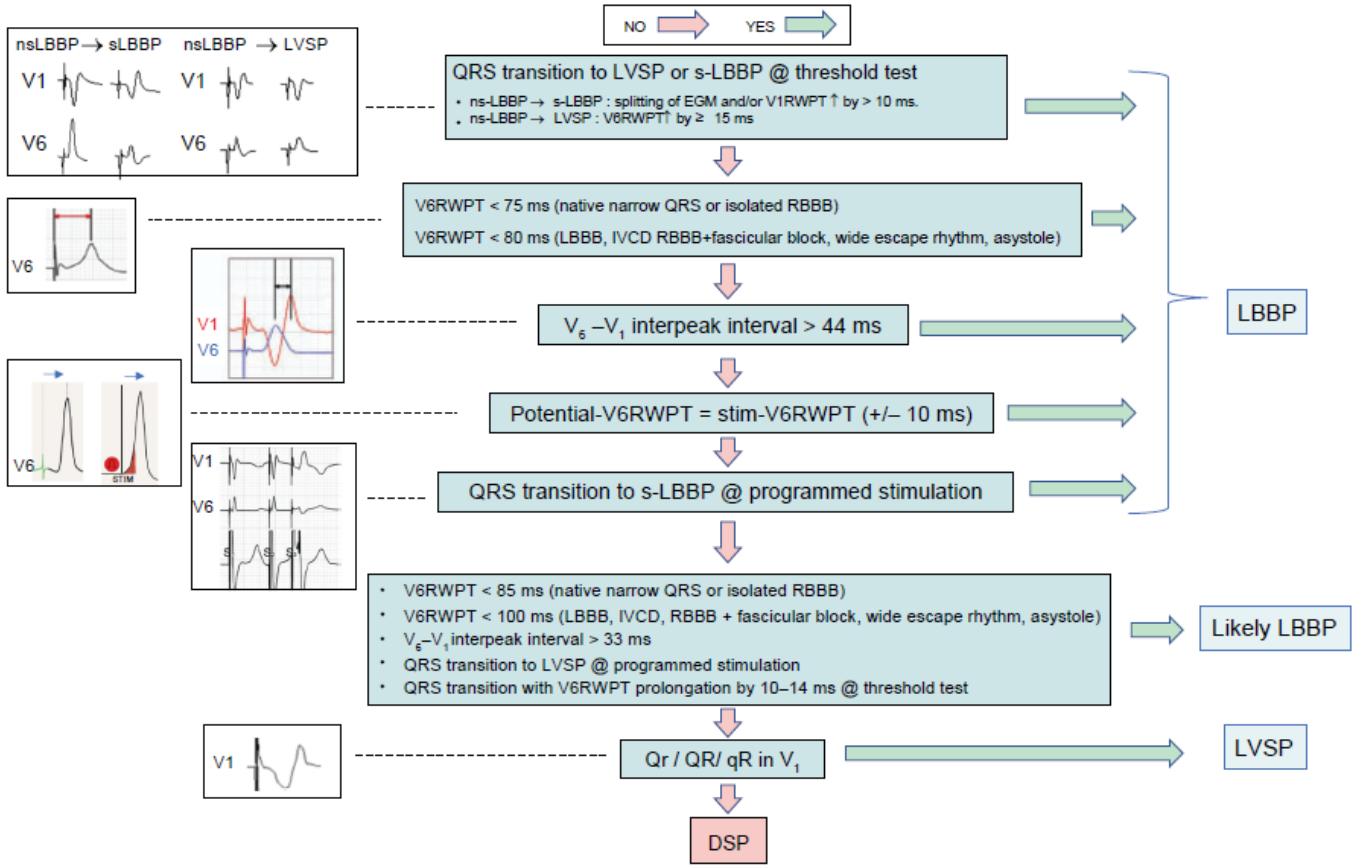
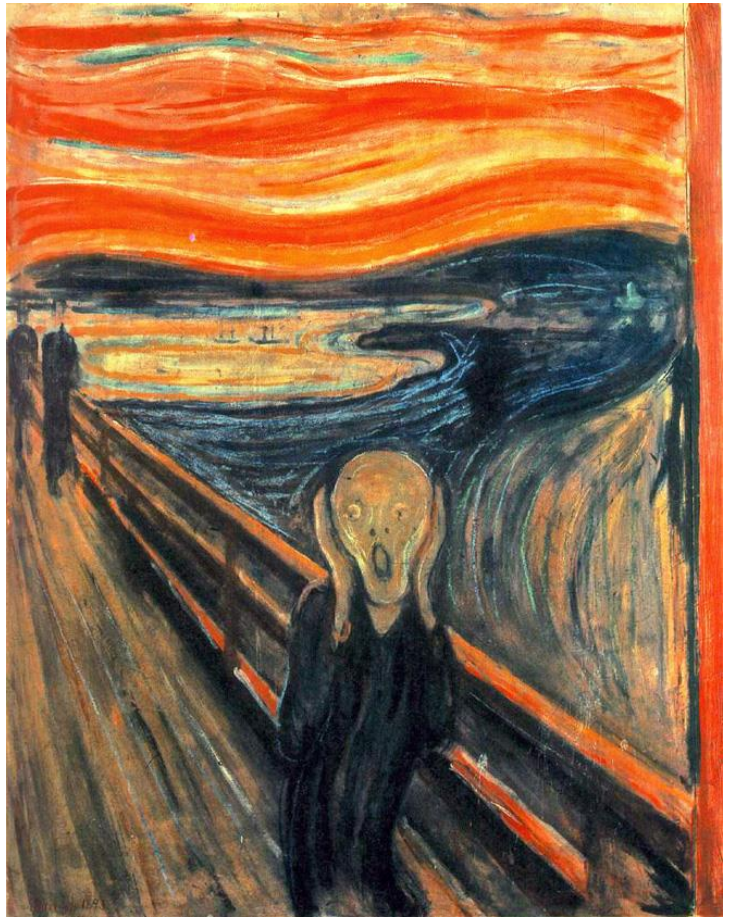
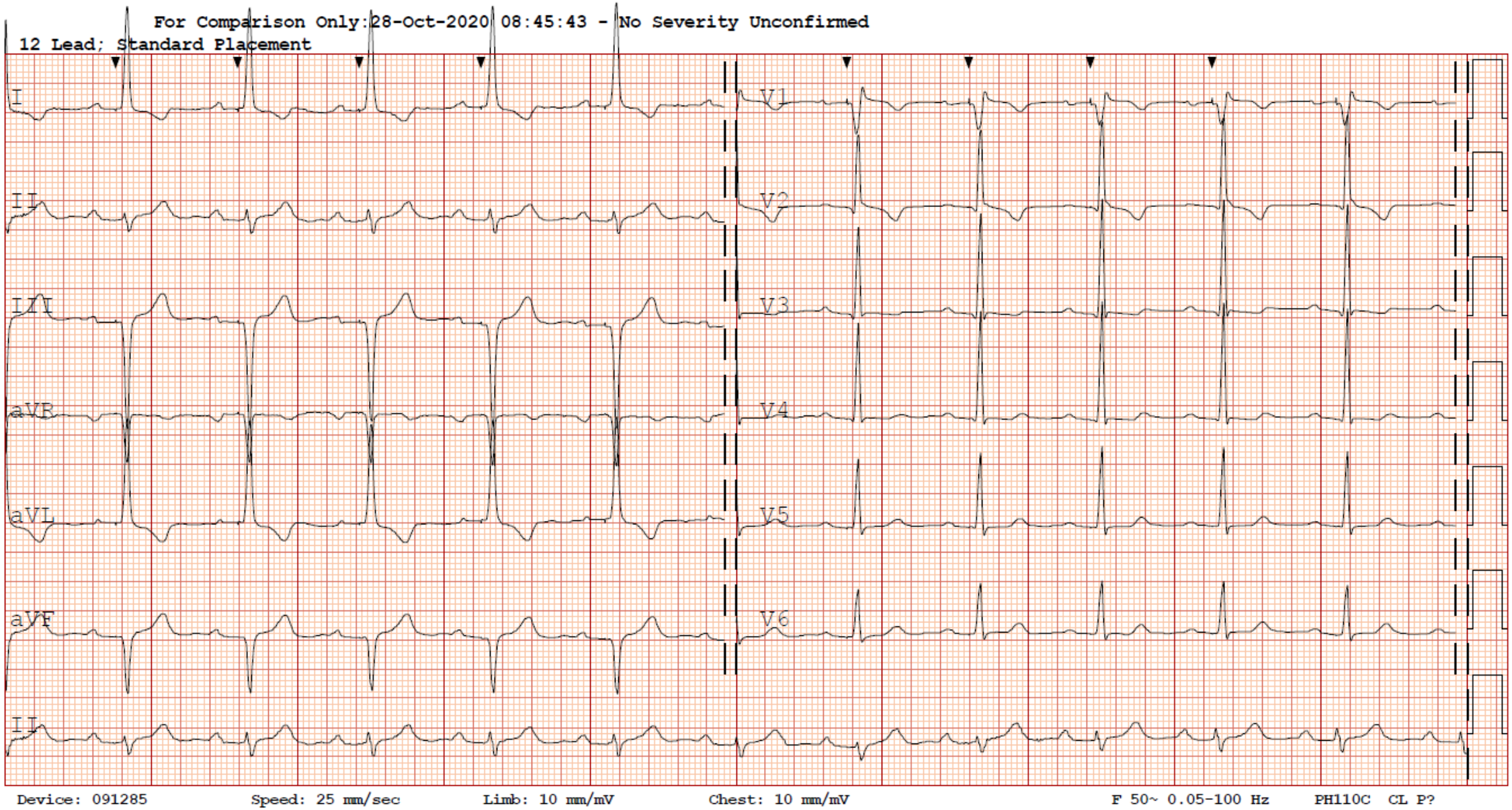
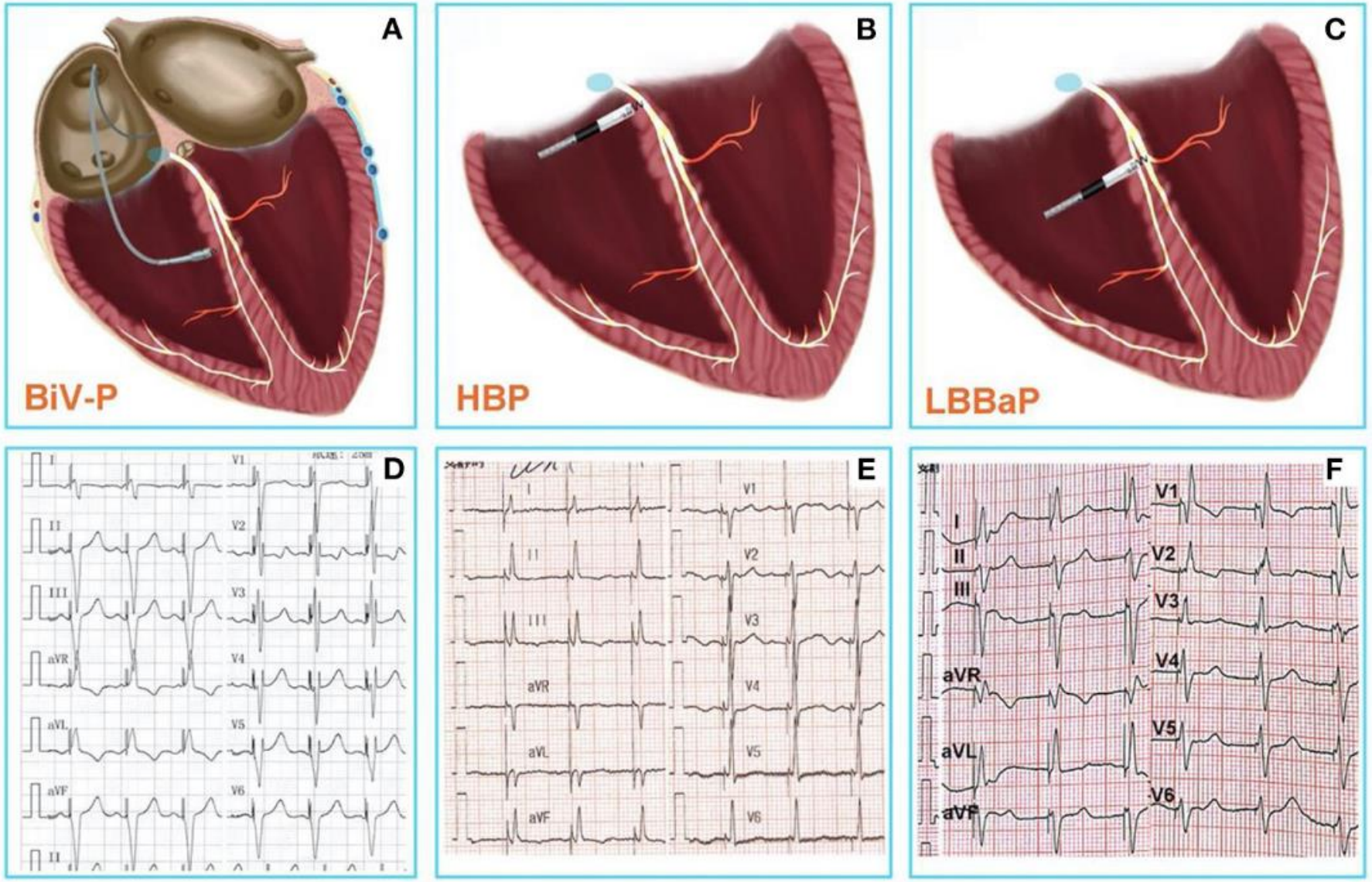


Figure 27 Algorithm for confirming conduction system capture with LBBAP. Some of the steps may be skipped according to operator preference, experience, or feasibility to perform particular measurements/manoeuvres. DSP = deep septal pacing; IVCD = intra-ventricular conduction delay; LBBAP = left bundle branch area pacing; LBBB = left bundle branch block; ns-LBBP = non-selective left bundle branch pacing; RBBB = right bundle branch block; RBBP = right bundle branch pacing; RWPT = R-wave peak time; s-LBBP = selective left bundle branch pacing.




For Comparison Only: 28-Oct-2020 08:45:43 - No Severity Unconfirmed
12 Lead; Standard Placement
I
II
III
aVR
aVL
aVF
II
V1
V2
V3
V4
V5
V6
Device: 091285
Speed: 25 mm/sec
Limb: 10 mm/mV
Chest: 10 mm/mV
F 50~ 0.05-100 Hz
PH110C CL P?


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

Indications du CSP

1) Pacing en cas de BAV

- Pacing anticipé > 20 % , idéalement avec FEVG < 40 % ou non
- Evite risque de «cardiopathie induite par le pacemaker»

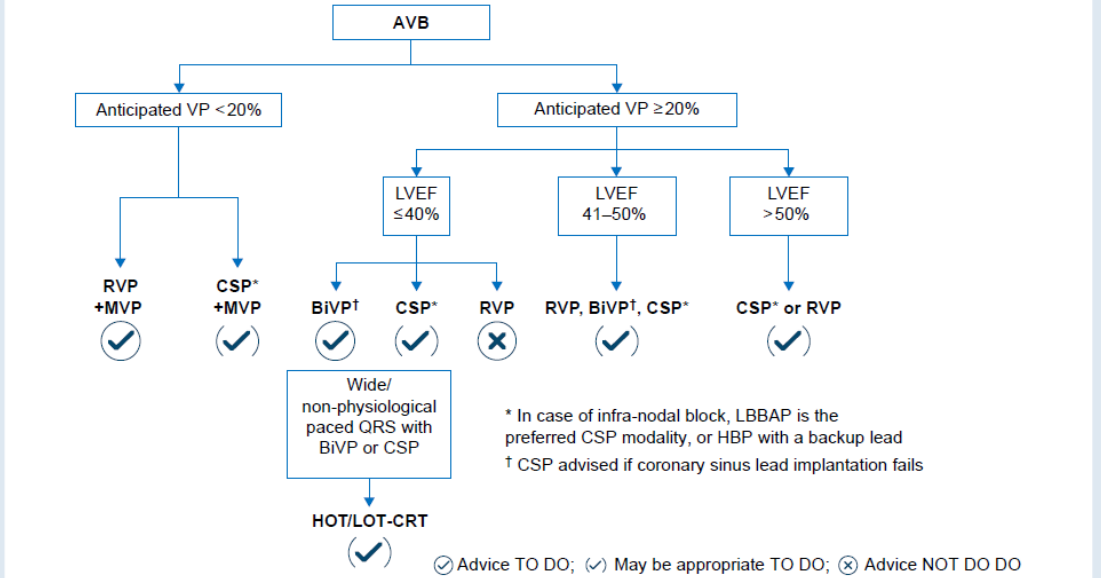
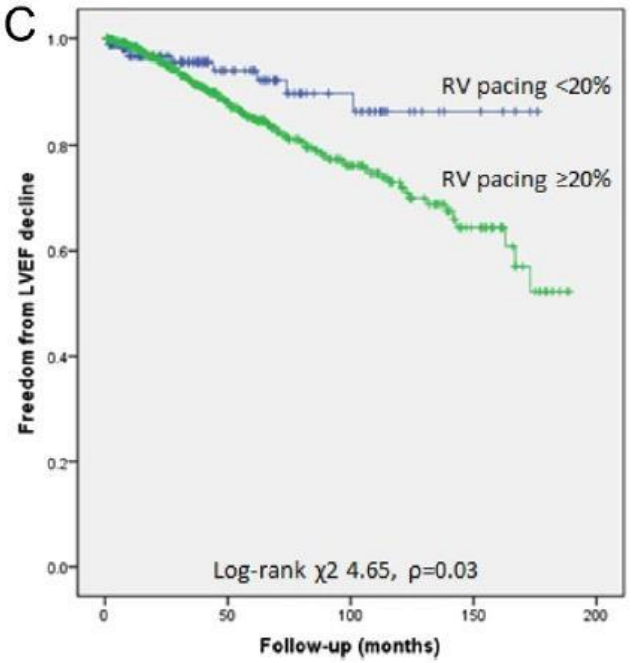


Figure 5 Summary of CSP indications in AVB. AVB, atrioventricular block; BiVP, biventricular pacing; CSP, conduction system pacing; HBP, His bundle pacing; HOT/LOT-CRT, His-optimized or left bundle-optimized cardiac resynchronization therapy; LBBAP, left bundle branch area pacing; LVEF, left ventricular ejection fraction; MVP, minimized ventricular pacing; RVP, right ventricular pacing.

Incidence and predictors of right ventricular pacing-induced cardiomyopathy in patients with complete atrioventricular block and preserved left ventricular systolic function

Erich L. Kiehl, MD,* Tarek Makki, MD,† Rahul Kumar, MD,† Divya Gumber, MD,† Deborah H. Kwon, MD,‡ John W. Rickard, MD, FHRS,§ Mohamed Kanj, MD, FHRS,§ Oussama M. Wazni, MD, FHRS,§ Walid I. Saliba, MD, FHRS,§ Niraj Varma, MD, FHRS,§ Bruce L. Wilkoff, MD, FHRS,§ Daniel J. Cantillon, MD, FHRS§



Indications du CSP

2) CSP pour patient avec HFrEF / HFmrEF (40-50%) avec BBG, en alternative au CRT

- Réduction de la durée du QRS (donc de l'asychronisme intraventriculaire)
- Amélioration du status fonctionel (NYHA)
- Amélioration de le FEVG
- Rôle moins claire si QRS large, sans BBG
- Pas d'amélioration d'endpoint dûr (mortalité, hospitalisations)

2') Chez les patients non répondeur à la CRT classique (QRS large, FEVG inchangée)

- À évaluer au cas par cas
- Amélioration de certains paramètres cliniques (FEVG, NYHA)

2'') «Upgrade» en cas cardiopathie induite par le pacemaker

- amélioration de la synchronisation VD/VG
- Evaluation lors du changement de boitier

Indications du CSP

3) Stratégie «pace-and-ablate» (ablation du nœud AV et pacing ventriculaire) pour la fibrillation auriculaire persistante symptomatique

- Indépendamment de la FEVG
- Réfractaire au contrôle de la fréquence par traitement médicamenteux / après isolation infructueuse des veines pulmonaires
- Directement en cas de FA permanente fortement symptomatique (patient «frail»)
- Amélioration de la FEVG et des symptômes

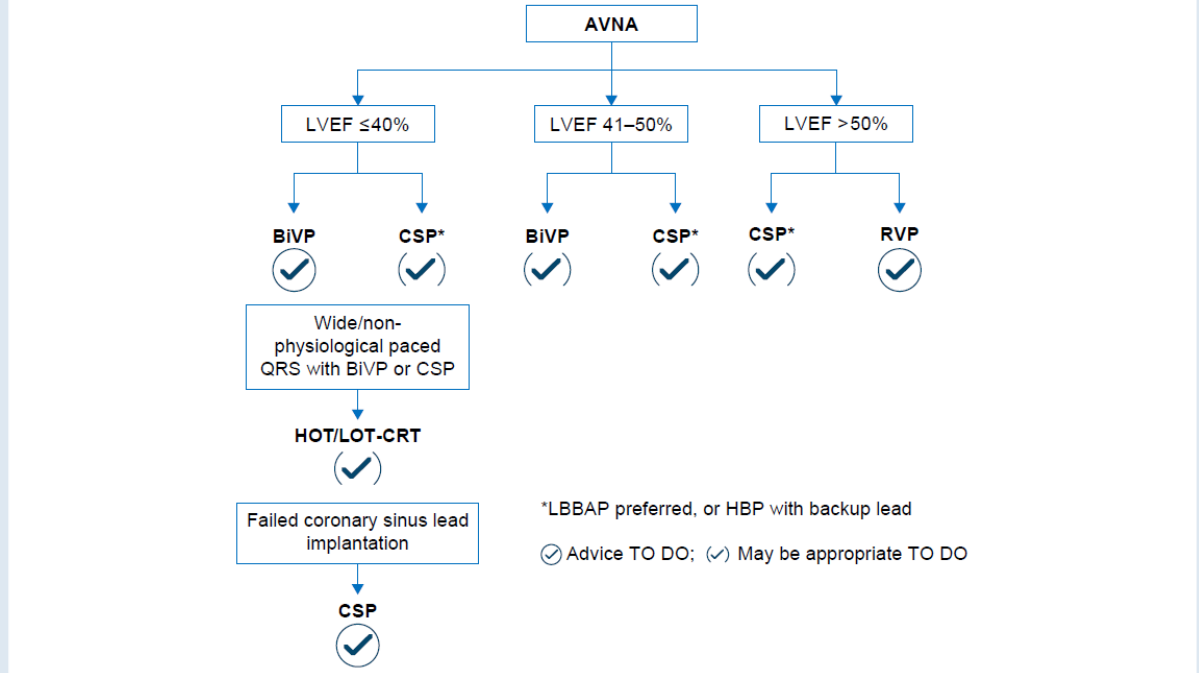
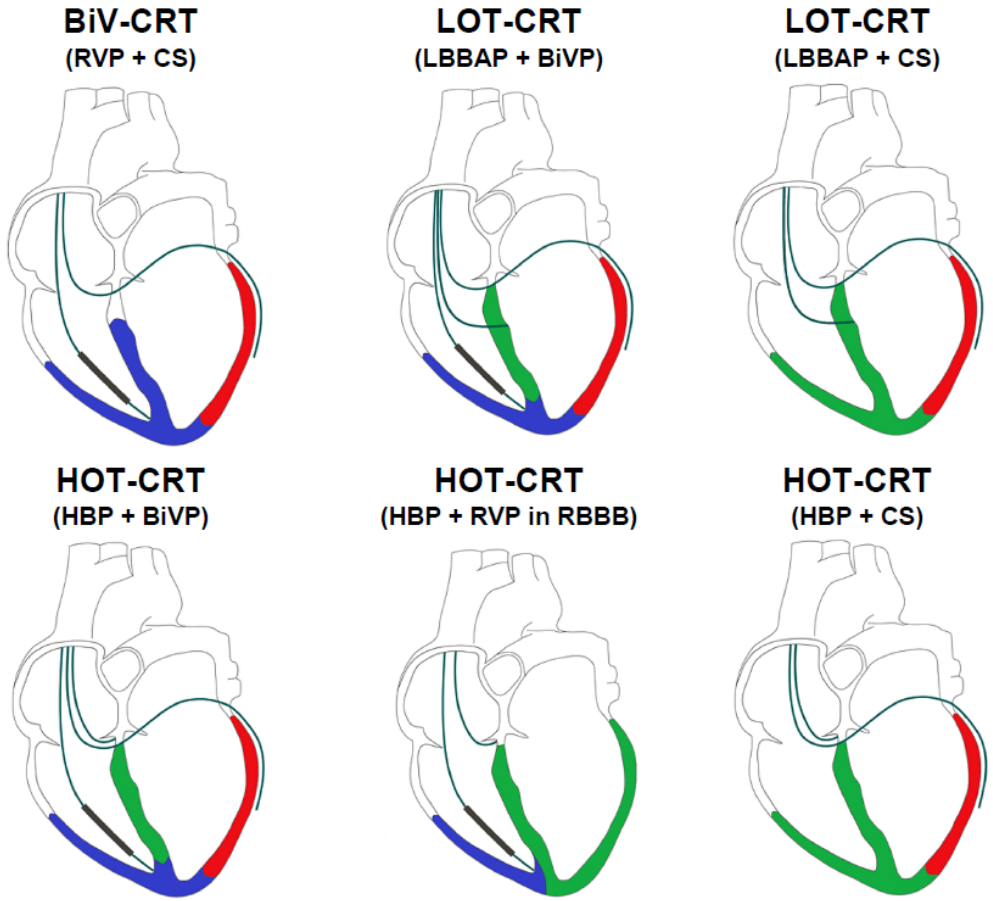


Figure 7 Indications for CSP in patients scheduled for AVNA. AVNA, atrioventricular nodal ablation; BiVP, biventricular pacing; CSP, conduction system pacing; HBP, His bundle pacing; HOT/LOT-CRT, His-optimized or left bundle-optimized cardiac resynchronization therapy; LBBAP, left bundle branch area pacing; LVEF, left ventricular ejection fraction; RVP, right ventricular pacing.

Michael Glikson et al European Society of Cardiology (ESC) clinical consensus statement on indications for conduction system pacing, with special contribution of the European Heart Rhythm Association of the ESC and endorsed by the Asia Pacific Heart Rhythm Society, the Canadian Heart Rhythm Society, the Heart Rhythm Society, and the Latin American Heart Rhythm Society, *EP Europace*, Volume 27, Issue 4, April 2025

CRT optimisée par stimulation des voies de conduction (HOT-CRT, LOT-CRT)



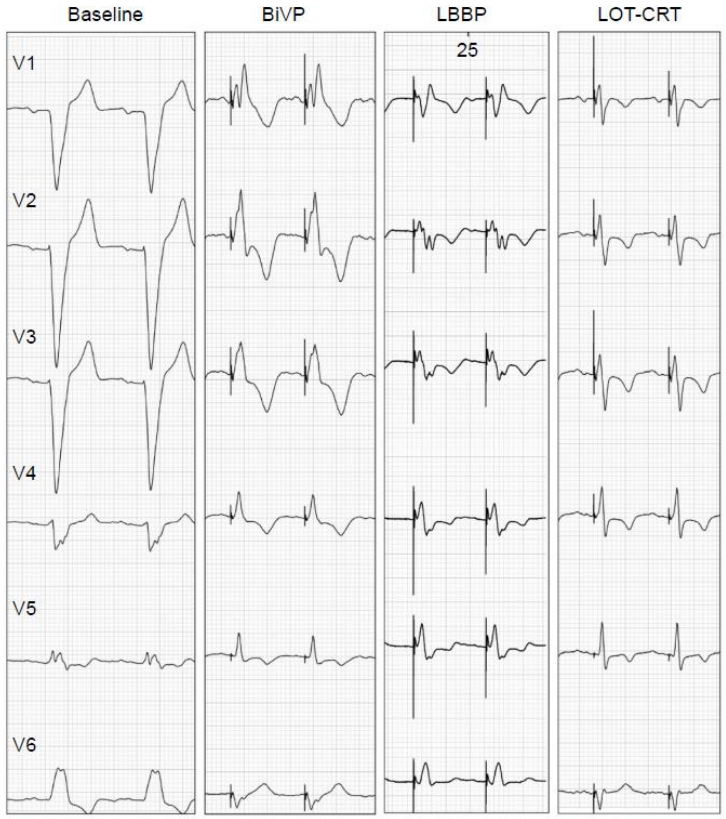


Figure 10 Superior electrical resynchronization with LOT-CRT compared with BiVP. Note the presence of QRS notching with BiVP and LBBP, which disappears with LOT-CRT. BiVP, biventricular pacing; LBBP, left bundle branch pacing; LOT-CRT, left bundle branch-optimized cardiac resynchronization therapy.

Complications (court et long terme) du CSP

Per-operative complications

- Septal perforation (0.0-14.1%)
- Right bundle branch block (19.9% with 6.3% permanent)
- Complete heart block (9.4% acute with 2.6% permanent)
- Intra-operative lead dislodgment (3.0%)
- Acute coronary syndrome (0.4-0.7%)
- Coronary artery fistula (1.4-2.0%)
- Coronary vein fistula/injury
- Septal hematoma
- Helix damage/fracture (0.8-5.0%)

Post-operative complications

- Delayed septal perforation (0.1-0.3%)
- Worsening tricuspid regurgitation (7.3-32.6%)
- Lead dislodgment (0.3-1.5%)
- Rise in threshold by >1 V (0.3-1.8%)
- Loss of LBB capture (0.3-11.5%)

Les pacemakers sans sonde («leadless pacemakers»)

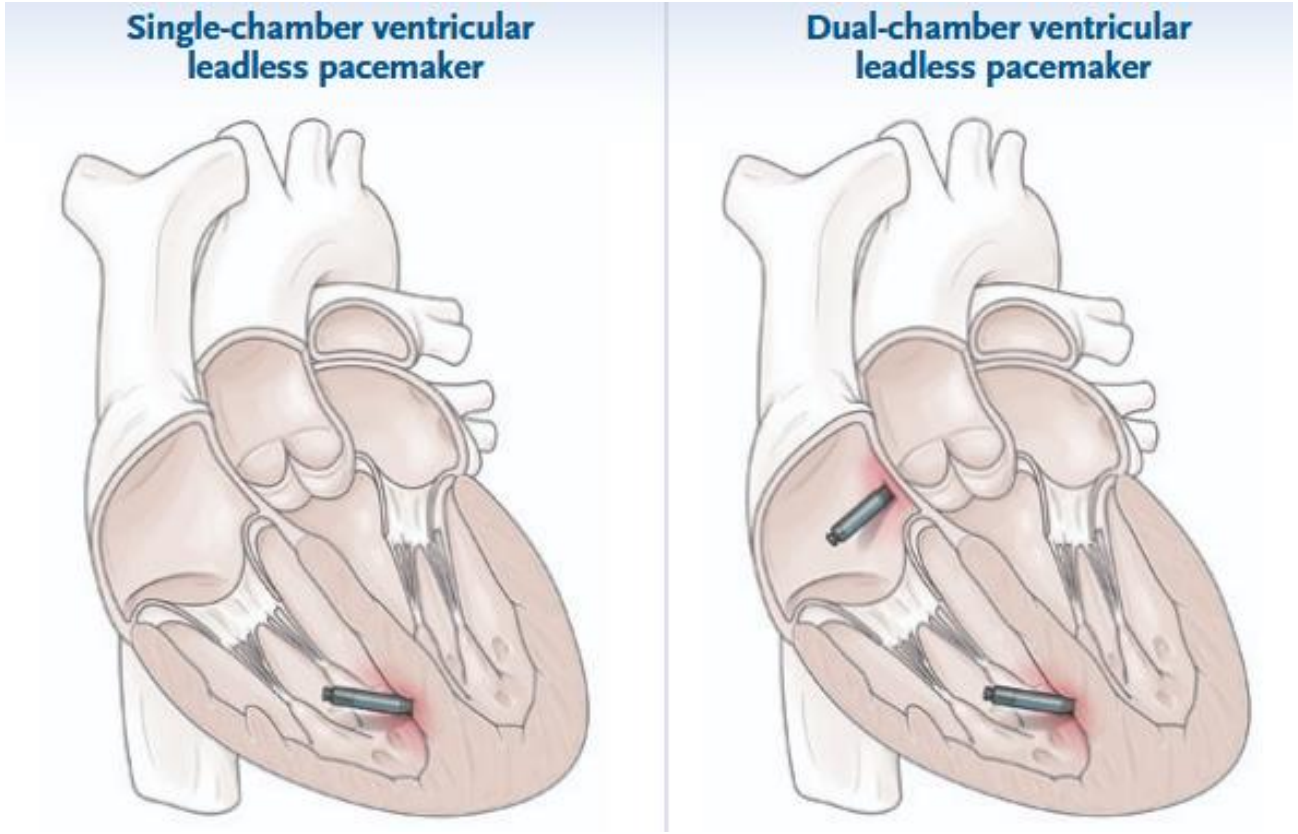
Micra® (Medtronic)

AVEIR® (Abbott)

Recommendations for using leadless pacing (leadless pacemaker)

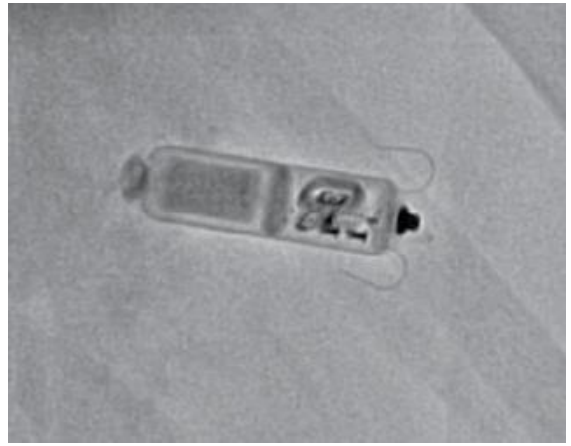
Recommendations	Class[a]	Level[b]
Leadless pacemakers should be considered as an alternative to transvenous pacemakers when no upper extremity venous access exists or when risk of device pocket infection is particularly high, such as previous infection and patients on haemodialysis.[45,47–50,450]	IIa	B
Leadless pacemakers may be considered as an alternative to standard single-lead ventricular pacing, taking into consideration life expectancy and using shared decision-making.[45,47–50]	IIb	C

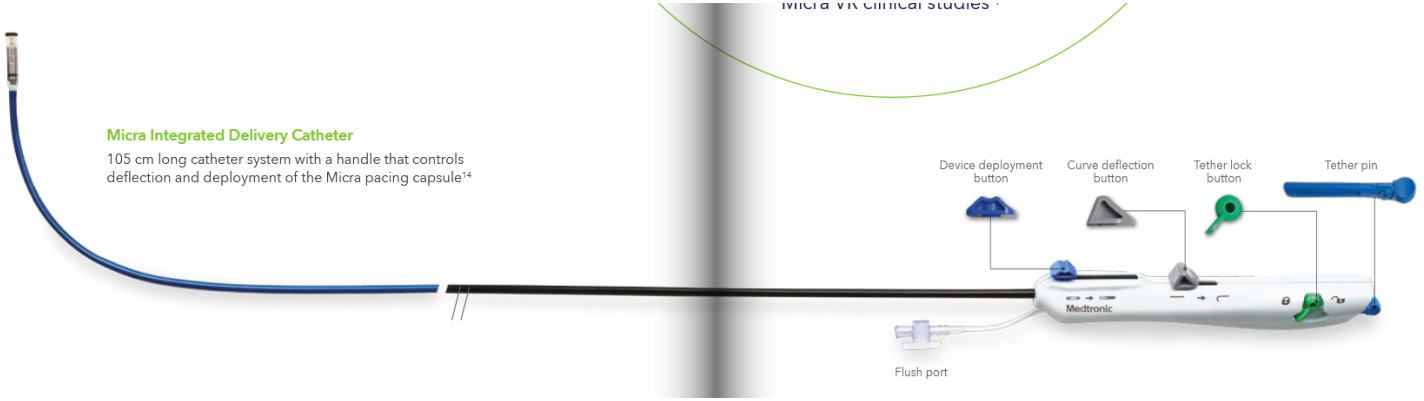
[a]Class of recommendation.
[b]Level of evidence.



Medtronic Micra VR (VVI) et AV (VDD)

Parameter	Description
Volume [cm³]	0.8
Diameter [mm]	6.7
Length [mm]	25.9
Weight [g]	1.75
Battery	Lithium-hybrid CFx silver vanadium oxide
Fixation mechanism	Four self-expanding nitinol tines
Device surface	Titanium and parylene C
Communication	Radiofrequency
Remote monitoring	Yes (but not automatically)
MRI compatibility	1.5 and 3 T full body





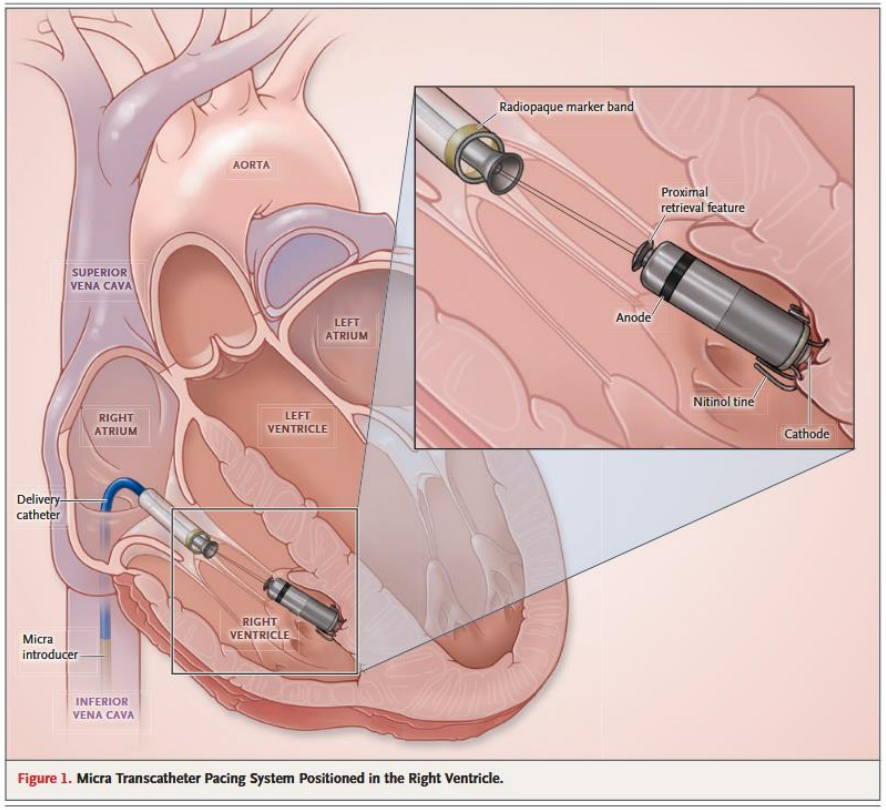
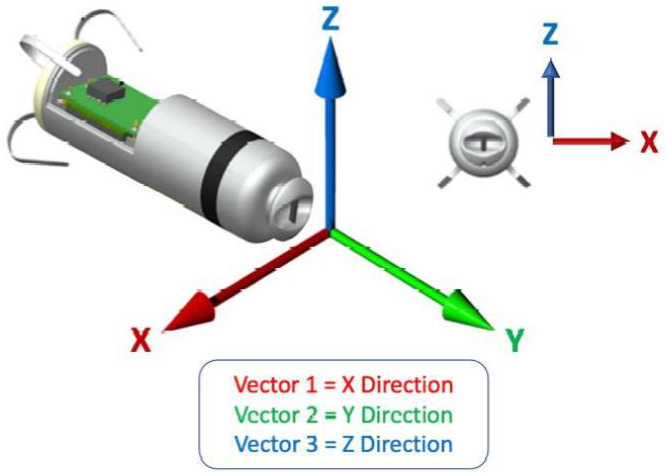


Figure 1. Micra Transcatheter Pacing System Positioned in the Right Ventricle.

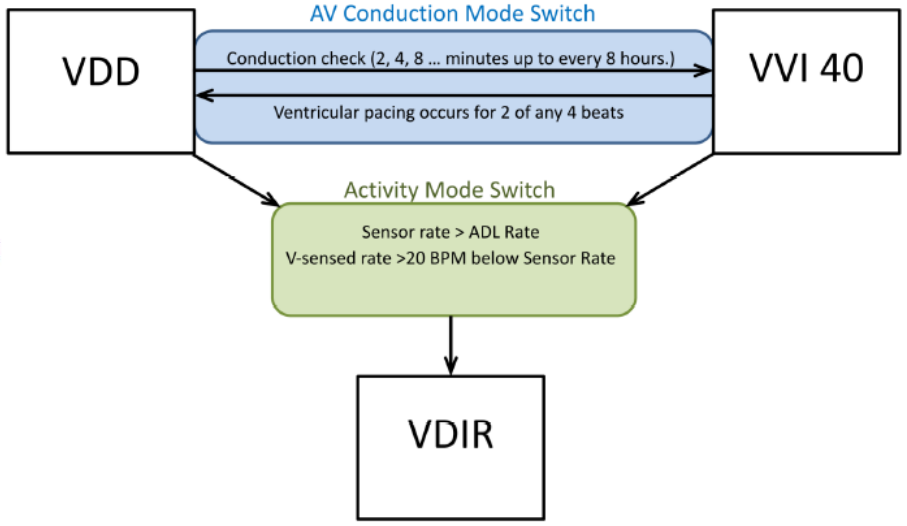
Medtronic Micra AV (VDD)

A three-axis accelerometer:

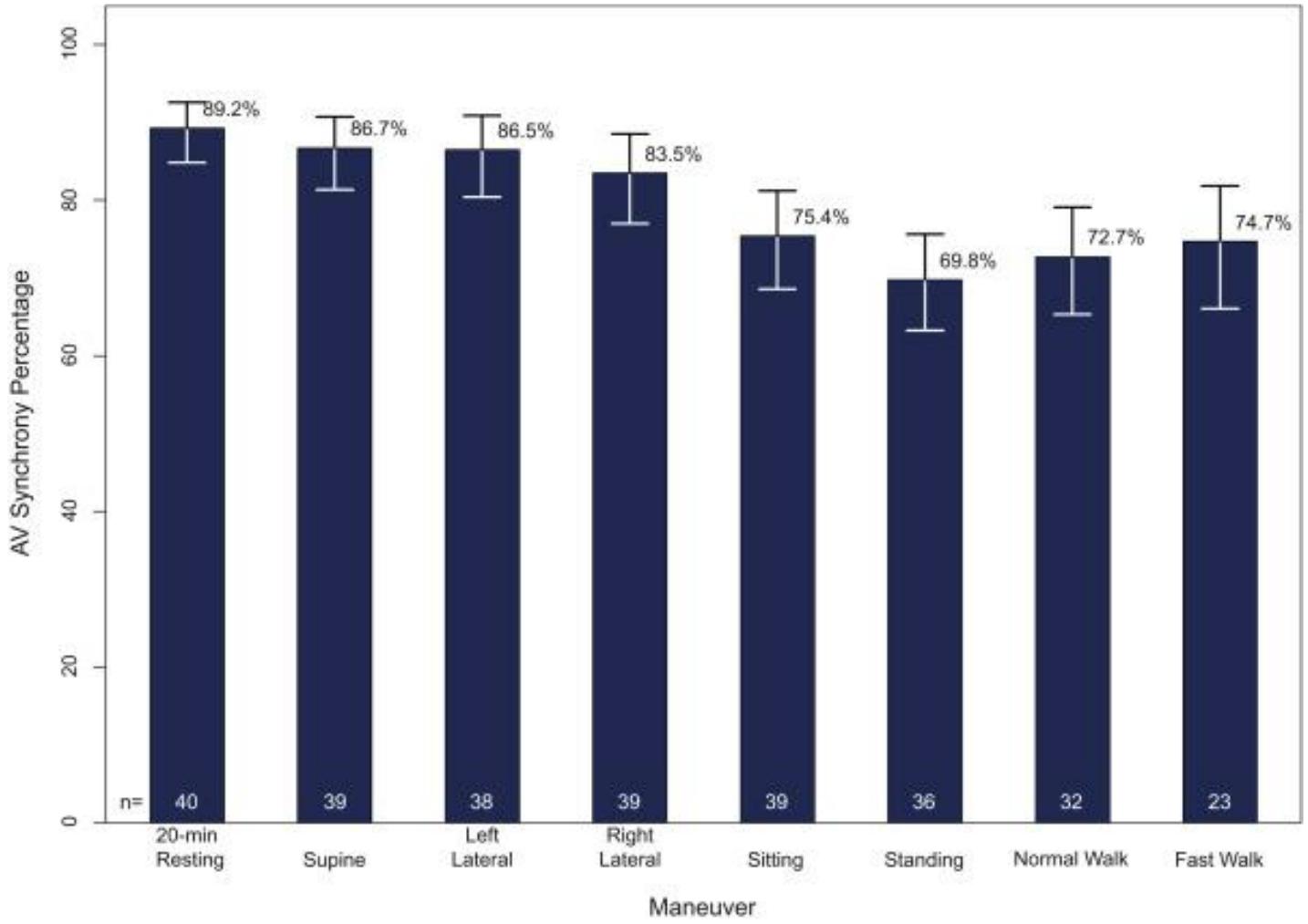
- **Measures the acceleration in relation to the 3 coordinate axes (changes in speed of a point)**
- **In Micra™ VR:**
  - **Responsible for *sensor function***
- **In Micra™ AV:**
  - **Responsible for *sensor function* + *atrial mechanical sensing* for VDD mode**



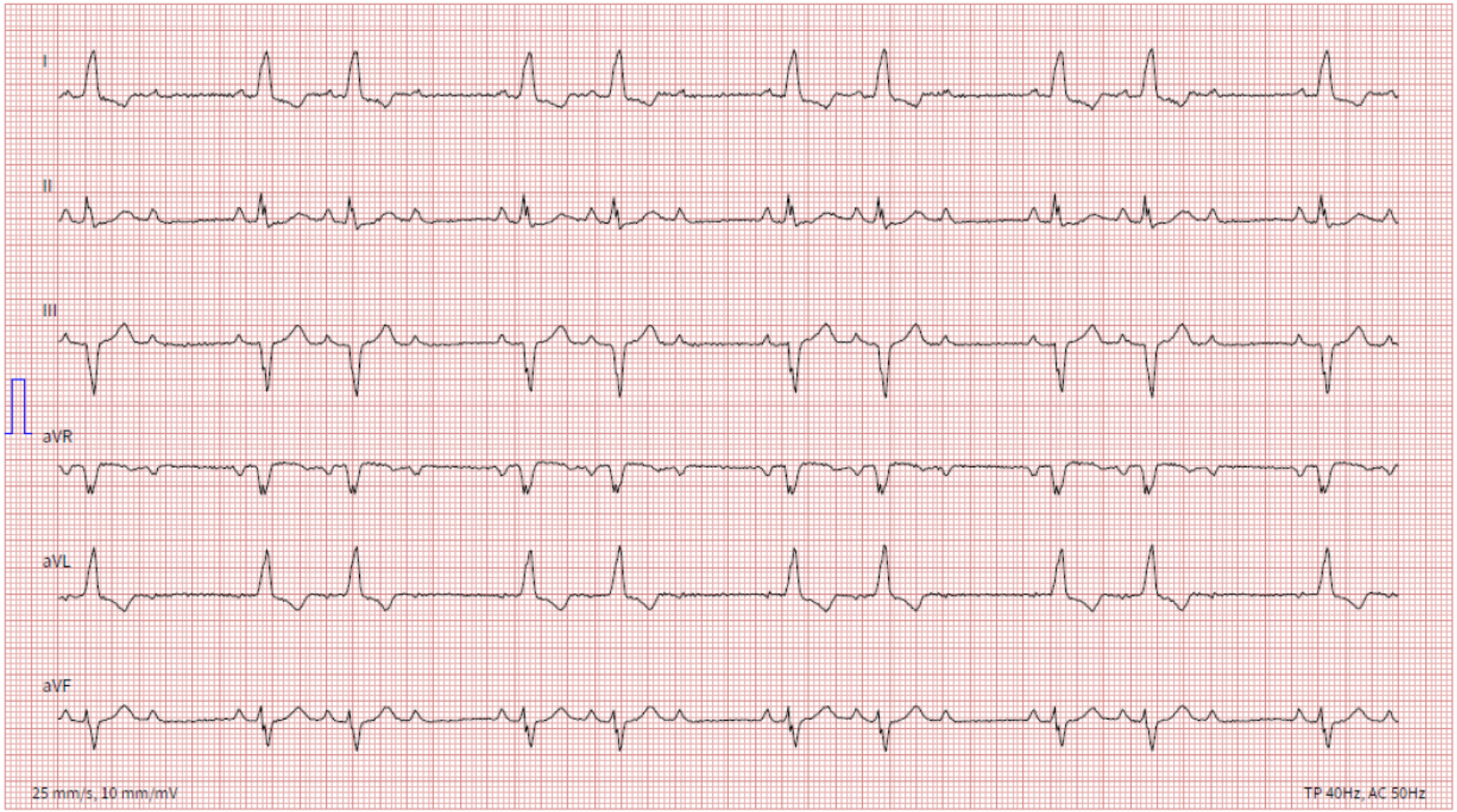
Mitacchione et al. *Rev Cardiovasc Med* 2021; 22: 395-401



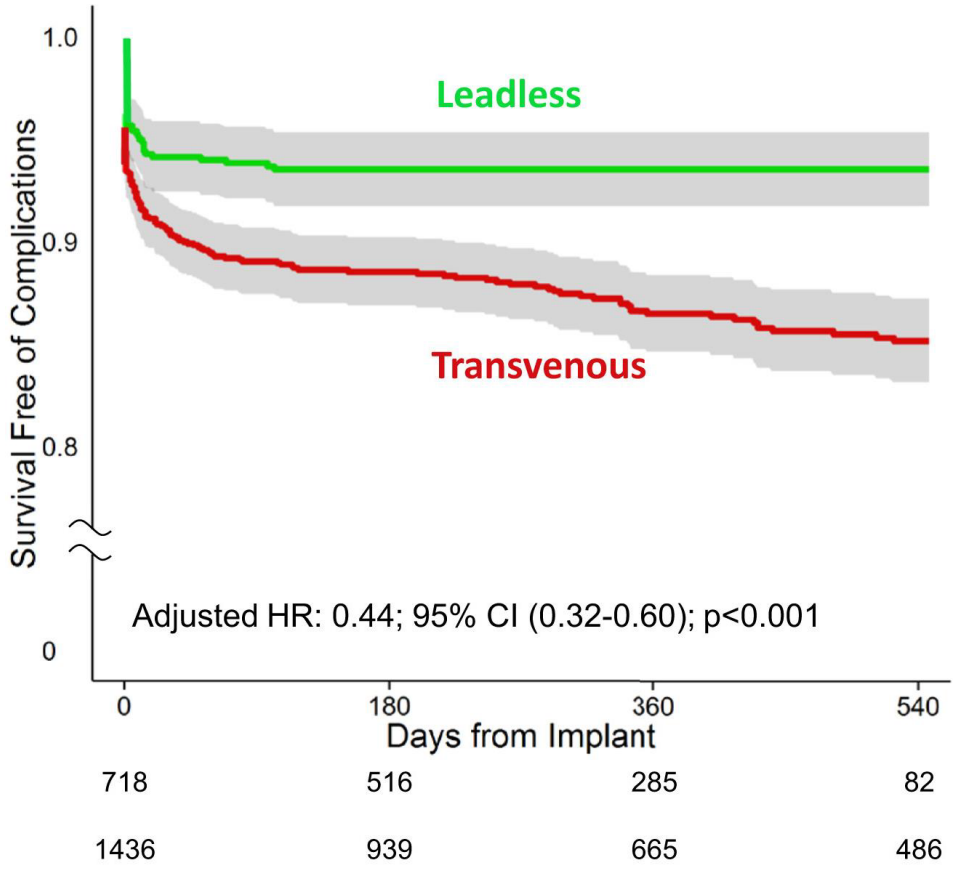
La limitation du Micra : la synchronisation atrio-ventriculaire

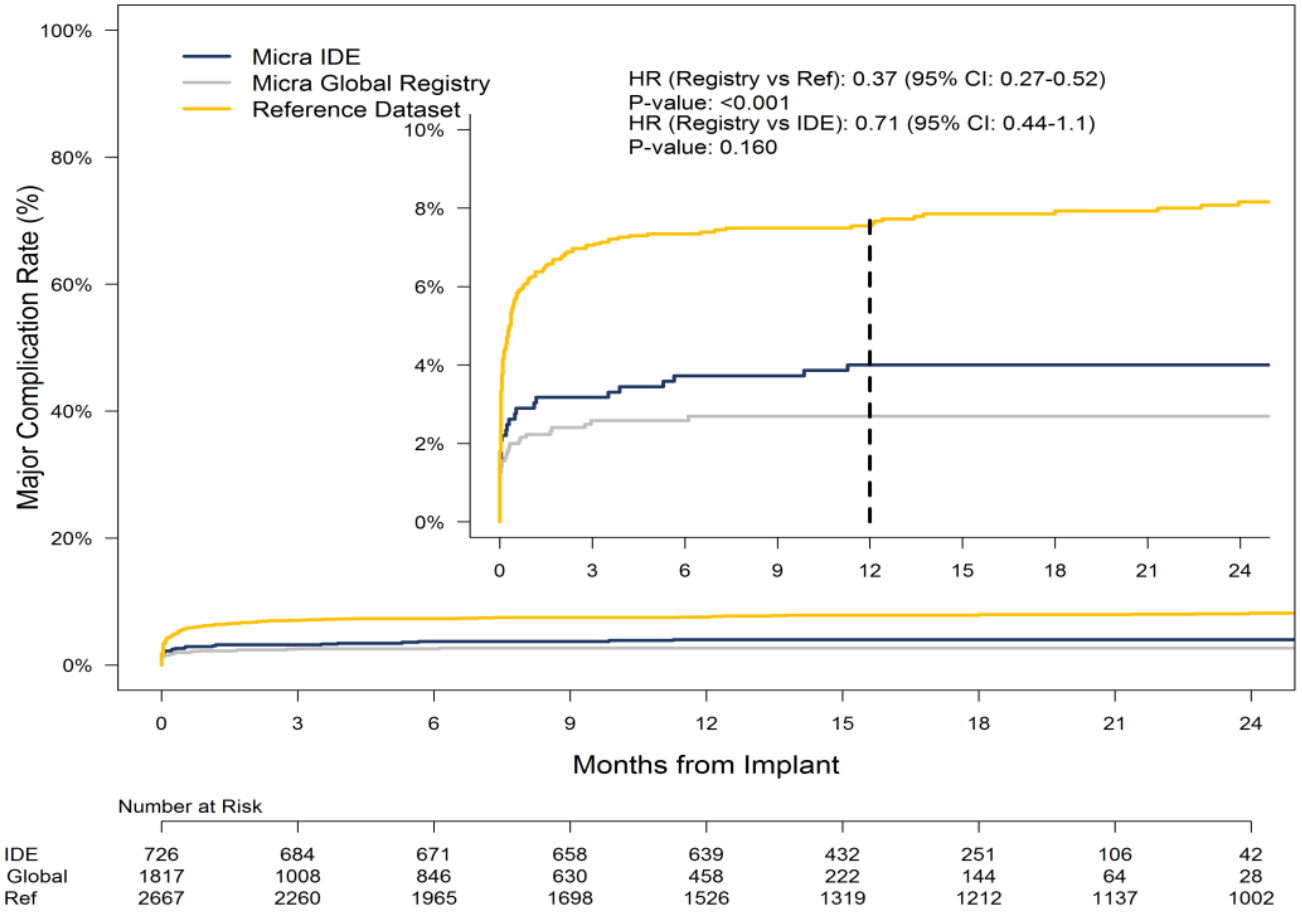


Limitation du Micra : la synchronisation atrio-ventriculaire



Complications entre PM transveineux et leadless

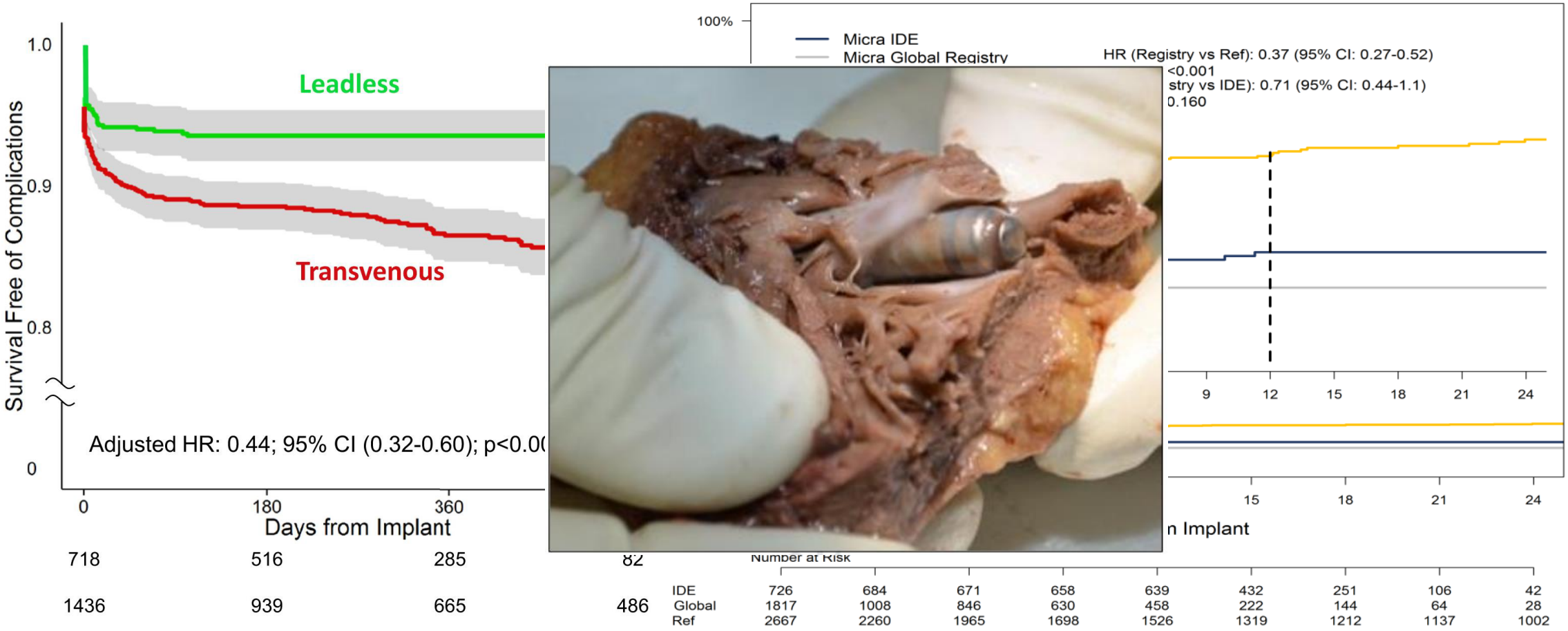




DanielJ.Cantillon,SrinivasR.Dukkipati,etal.Comparative study of acute and mid term complications with leadless and transvenous cardiac pacemakers. HeartRhythm, Volume15

12-Month results from the Micra AV post-approval registry, Garweg et al, Heart Rhythm 2024

Complications entre PM transveineux et leadless



DanielJ.Cantillon,SrinivasR.Dukkipati,etal.Comparative study of acute and mid term complications with leadless and transvenous cardiac pacemakers. HeartRhythm, Volume15

12-Month results from the Micra AV post-approval registry, Garweg et al, Heart Rhythm 2024

AVEIR (Abbott) leadless pacemaker

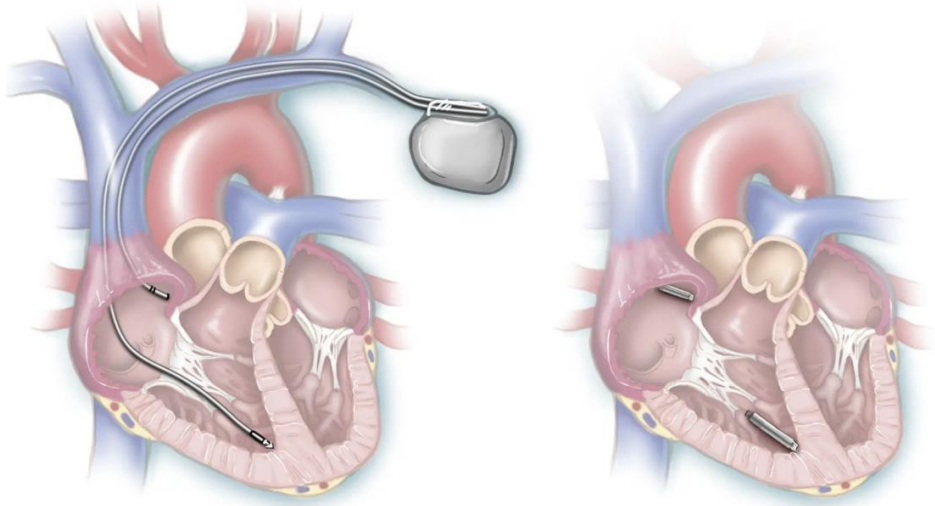
A: Atrial

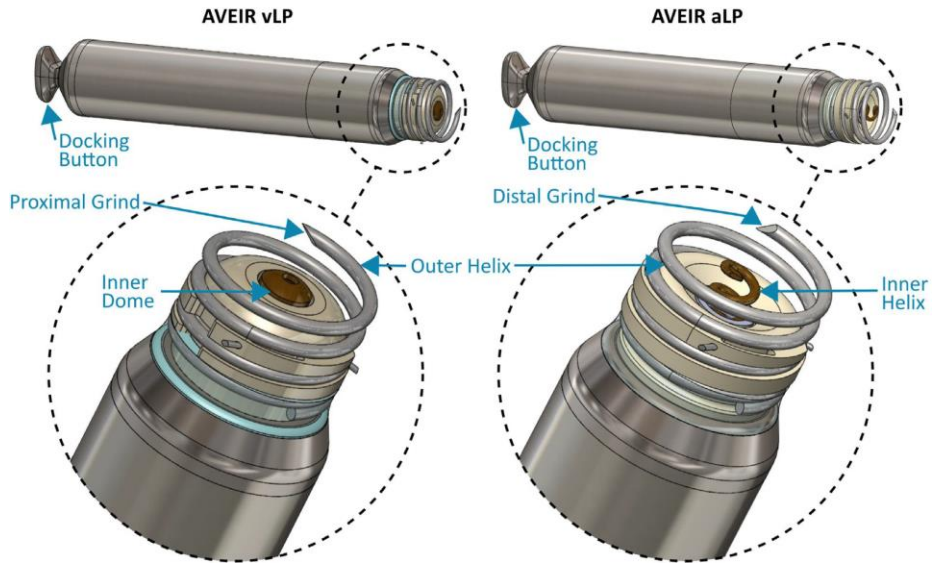
V: Ventricular

E: Expandable

I: i2i

R: Retrievable





The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

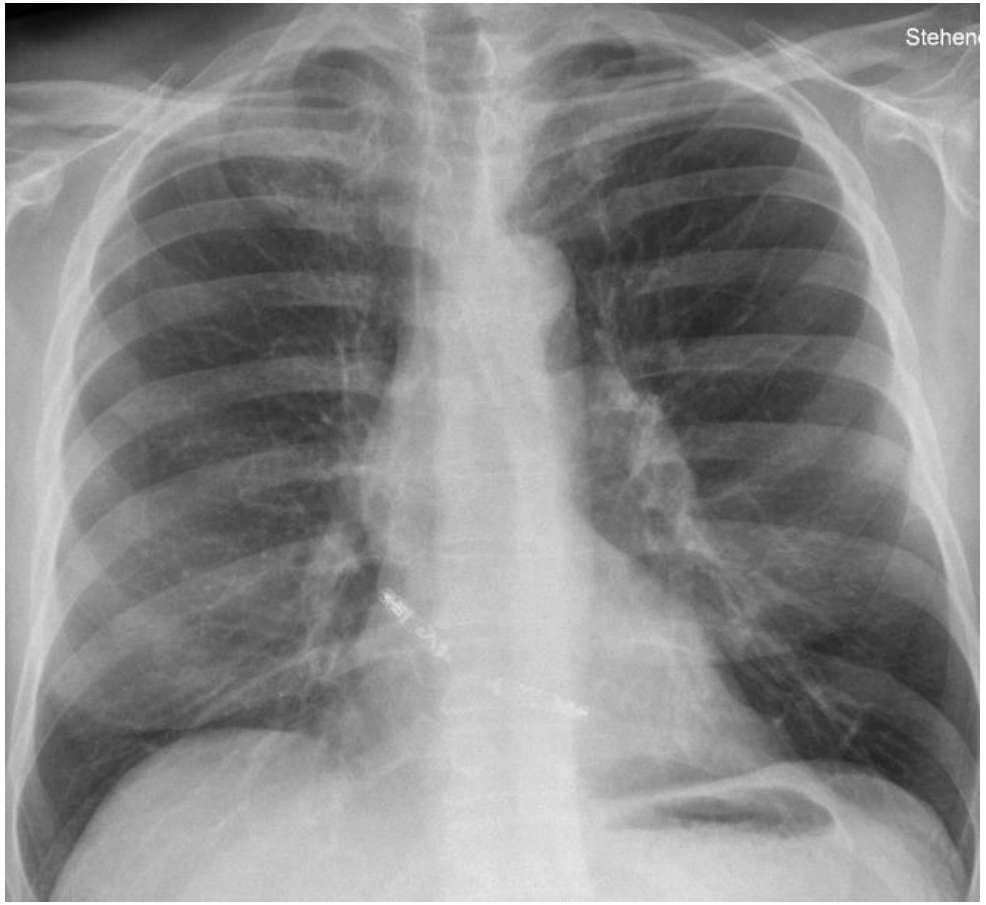
A Dual-Chamber Leadless Pacemaker

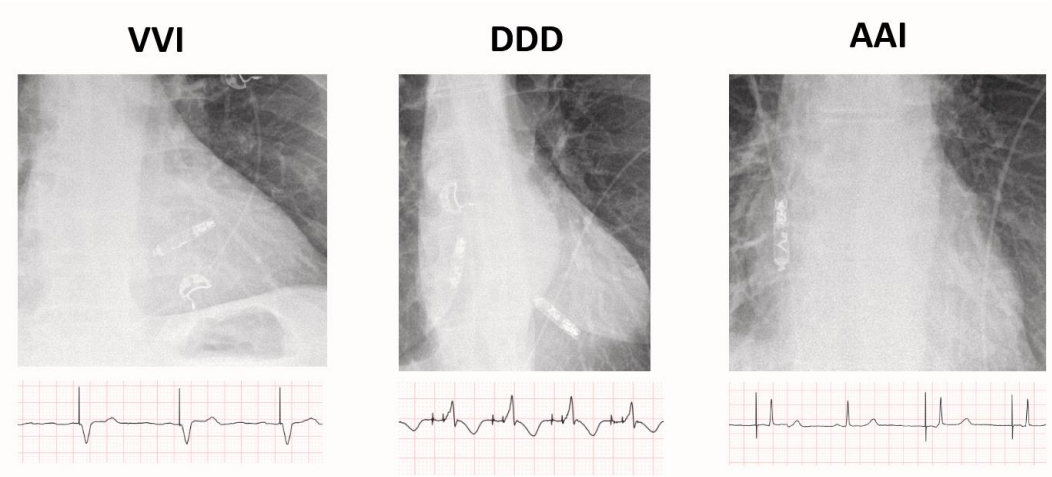
Reinoud E. Knops, M.D., Ph.D., Vivek Y. Reddy, M.D., James E. Ip, M.D., Rahul Doshi, M.D., Derek V. Exner, M.D., M.P.H., Pascal Defaye, M.D., Robert Canby, M.D., Maria Grazia Bongiorni, Gerhard Hindricks, M.D., Petr Neužil, M.D. Karel T.N. Breeman, M.D., Jordan R. Nevo, I Chris Hubbard, M.B.A., and Daniel for the Aveir DR i2i Study Inv

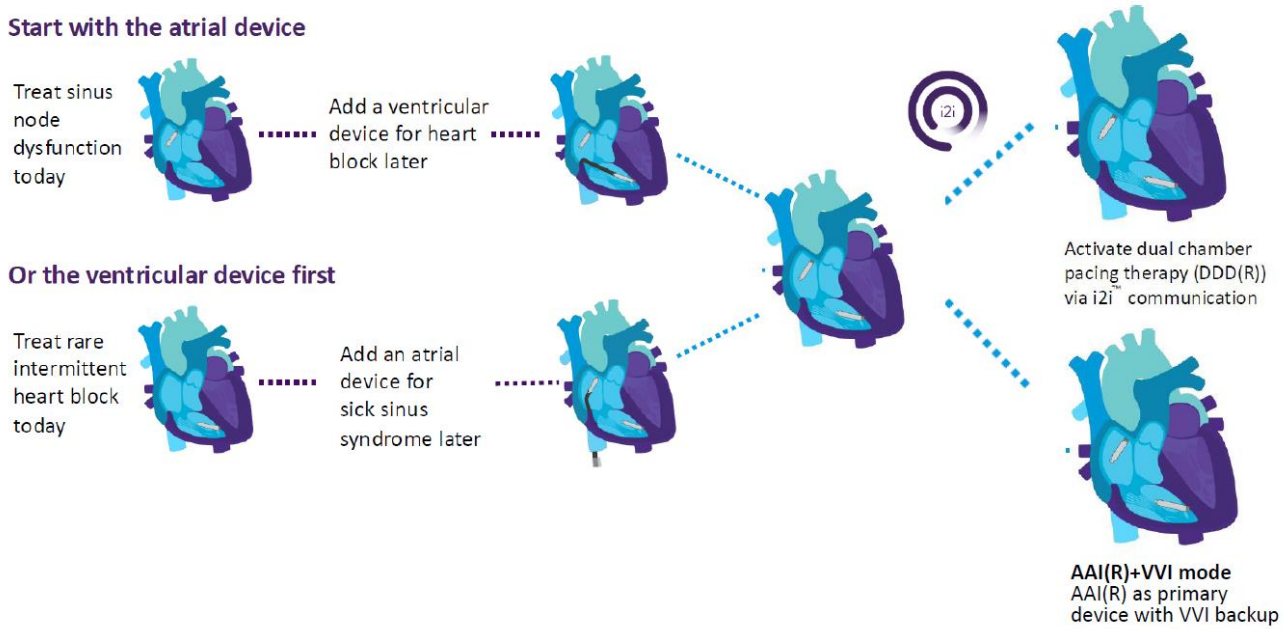
Study:

- **300 Patients**
- **63% Sick Sinus**
- **98% Implant success**
- **97% AV synchrony success**

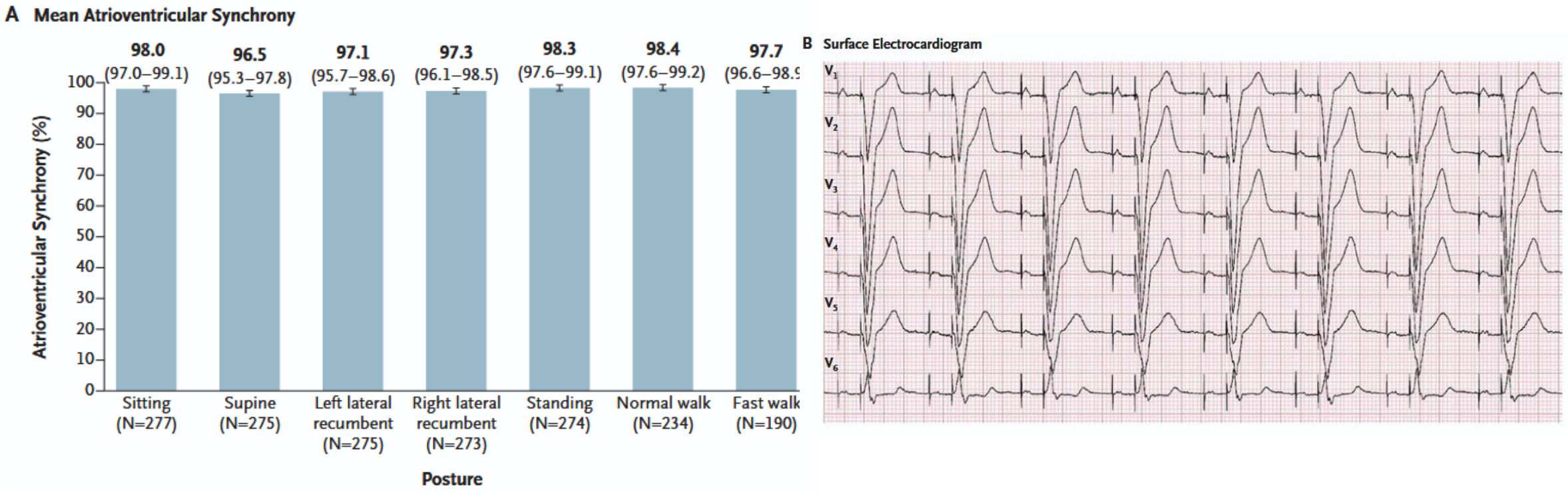
Communication implant vers implant (i2i)







Synchronmisation AV optimisée



Epuisement de la batterie…

Implant auriculaire

AVEIR AR LP

Pacing Rate	Pace Amplitude	% Pacing	LONGEVITY (YRS) Impedance 300 Ω	400 Ω
50 bpm	1.25 V	100%	6.2	7.1
		50%	7.1	8.1
		0%	8.3	9.3
50 bpm	2.5 V	100%	3.9	4.7
		50%	5.3	6.2
		0%	8.3	9.3
60 bpm	1.25 V	100%	5.3	6.1
	2.5 V	100%	3.3	3.9
	5.0 V	100%	1.1	1.4

315 Ω Mean atrial device impedance at 3-month IDE follow-up[2]

Implant ventriculaire

AVEIR VR LP

Pacing Rate	Pace Amplitude	% Pacing	LONGEVITY (YRS) Impedance 500 Ω	600 Ω
50 bpm	1.25 V	100%	11.4	12.2
		50%	12.7	13.5
		0%	14.3	15.0
50 bpm	2.5 V	100%	7.7	8.5
		50%	10.0	10.9
		0%	14.3	15.0
60 bpm	1.25 V	100%	9.8	10.5
	2.5 V	100%	6.6	7.3
	5.0 V	100%	2.5	2.8

595 Ω Mean ventricular device impedance at 3-month IDE follow-up[2]

Particularités entre PM transveineux et leadless

Table 2. Characteristics of Transvenous and Leadless Pacemakers.

Characteristic	Transvenous Pacemaker	Leadless Pacemaker
Implant complications	Valve injury or damage Pocket hematoma Lead dislodgement Hemo/pneumothorax	Vascular injury Groin bleeding or hematoma Device embolization Cardiac perforation or tamponade
Infection	High risk	Low risk
Extraction	Significant experience	Limited experience
Atrial pacing	Capable	Capable
Cardiac resynchronization	Capable	No
Recovery	Prolonged	Short
Battery life*	Up to 17 years (median, 10.8)	Up to 27 years (median, 12.1)
Remote monitoring	Capable	Only one type (Micra) currently capable
MRI-conditional	Yes	Yes
Cost	Low	High

*Battery life is less for dual-chamber leadless pacemakers when they are programmed to communicate, with a mean of 6.4 years for the atrial device and 11.3 years for the ventricular device.[15] MRI denotes magnetic resonance imaging.

Les coûts

- Pacemaker conventionnel double chambre : 4‘000 – 6‘000.-
- Leadless 1 chambre : 10‘000 – 14‘000.-
- Leadless 2 chambres : 25‘000.-

CH: Les champions des implantations

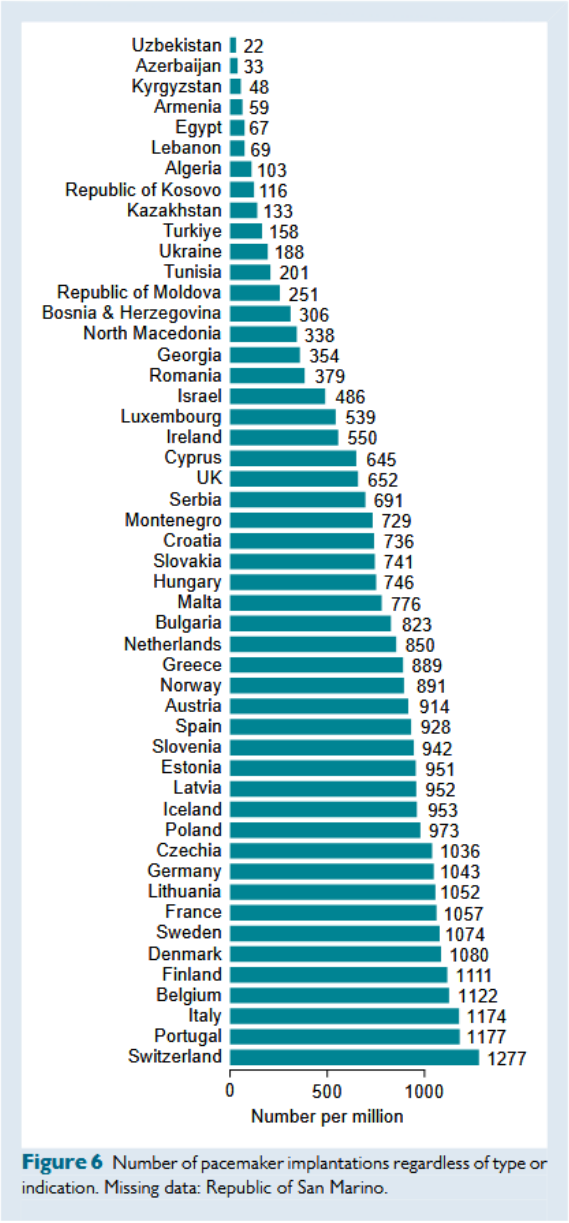


Figure 6 Number of pacemaker implantations regardless of type or indication. Missing data: Republic of San Marino.

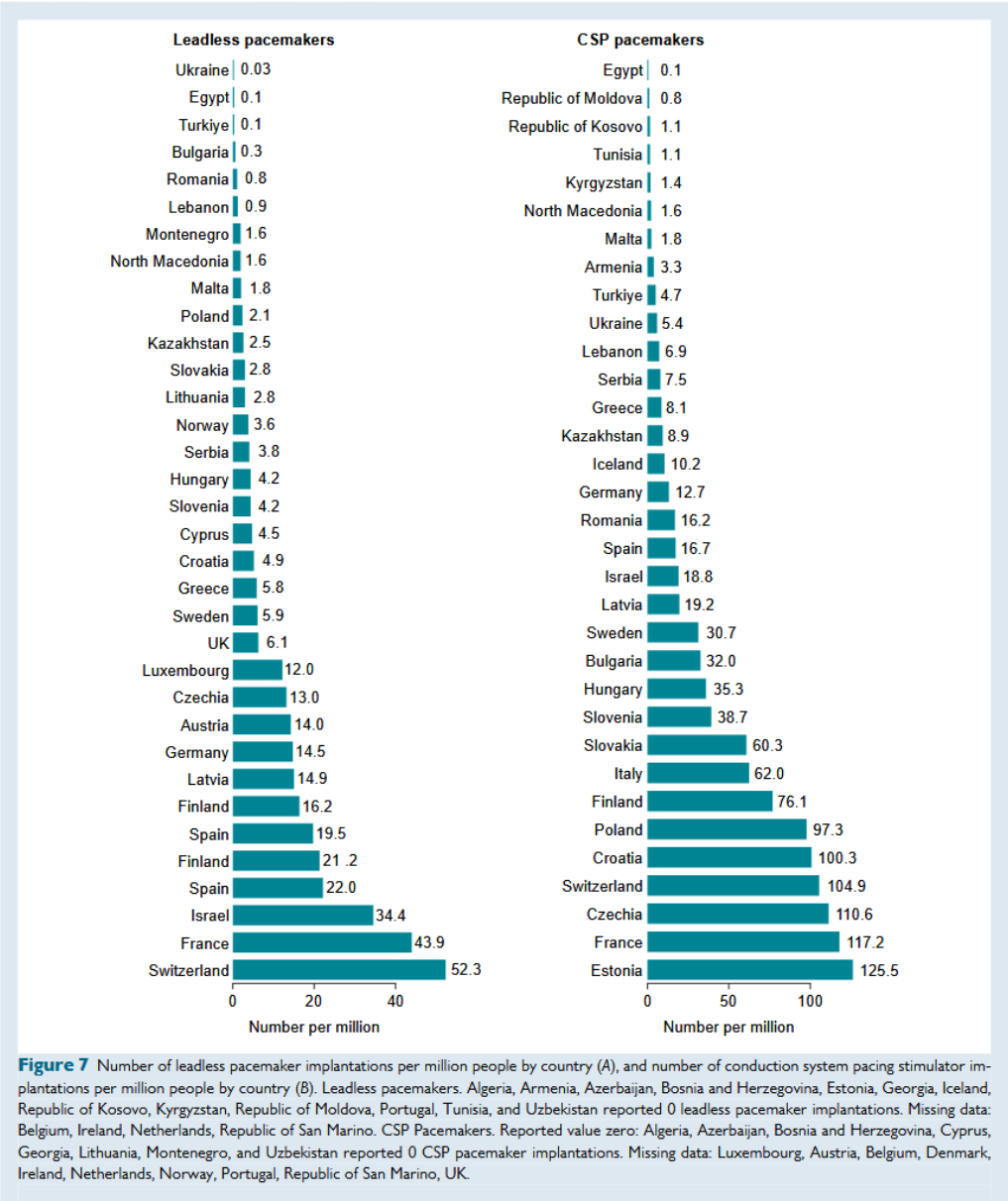
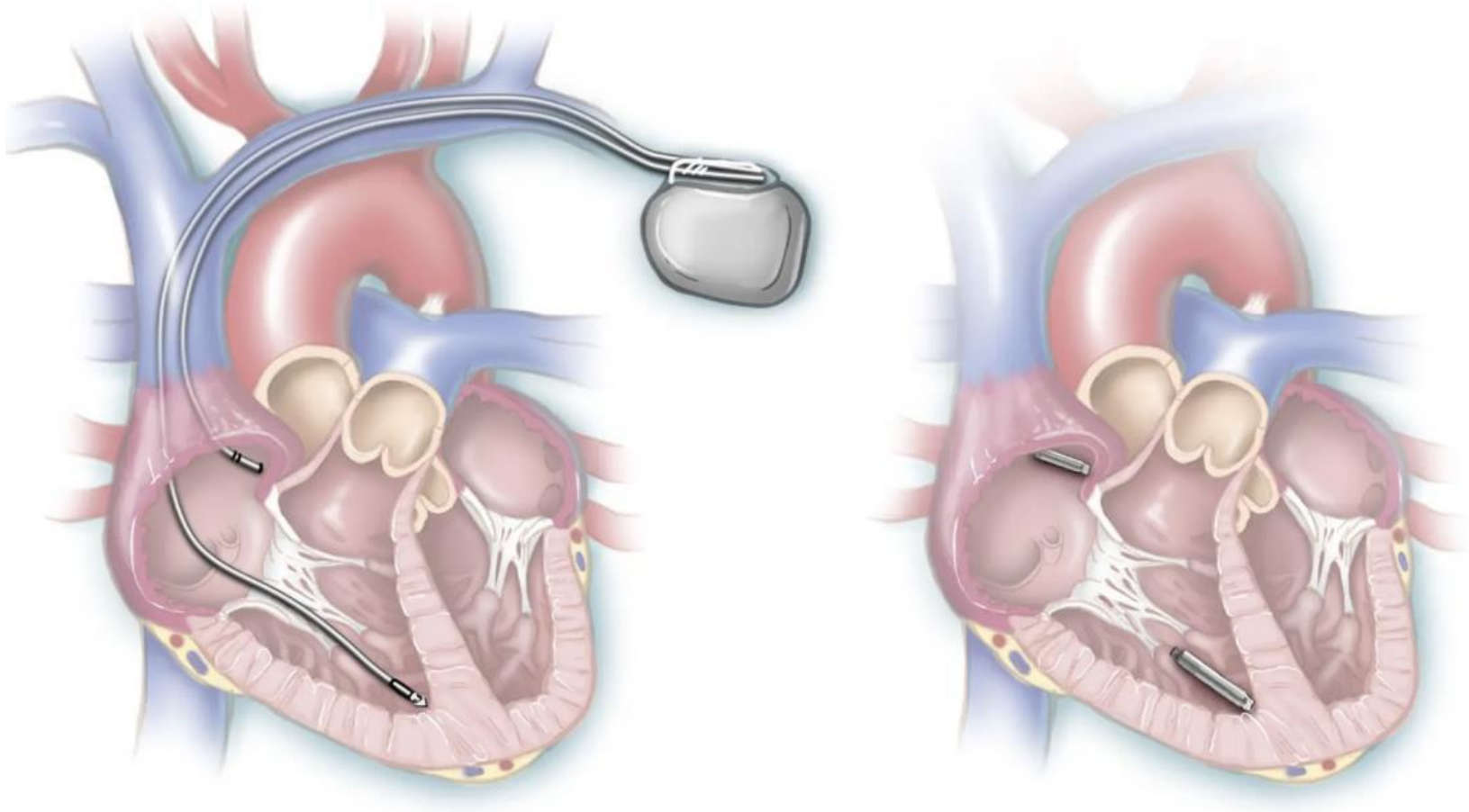


Figure 7 Number of leadless pacemaker implantations per million people by country (*A*), and number of conduction system pacing stimulator implantations per million people by country (*B*). Leadless pacemakers. Algeria, Armenia, Azerbaijan, Bosnia and Herzegovina, Estonia, Georgia, Iceland, Republic of Kosovo, Kyrgyzstan, Republic of Moldova, Portugal, Tunisia, and Uzbekistan reported 0 leadless pacemaker implantations. Missing data: Belgium, Ireland, Netherlands, Republic of San Marino. CSP Pacemakers. Reported value zero: Algeria, Azerbaijan, Bosnia and Herzegovina, Cyprus, Georgia, Lithuania, Montenegro, and Uzbekistan reported 0 CSP pacemaker implantations. Missing data: Luxembourg, Austria, Belgium, Denmark, Ireland, Netherlands, Norway, Portugal, Republic of San Marino, UK.

Le pacing dans 10 ans ?

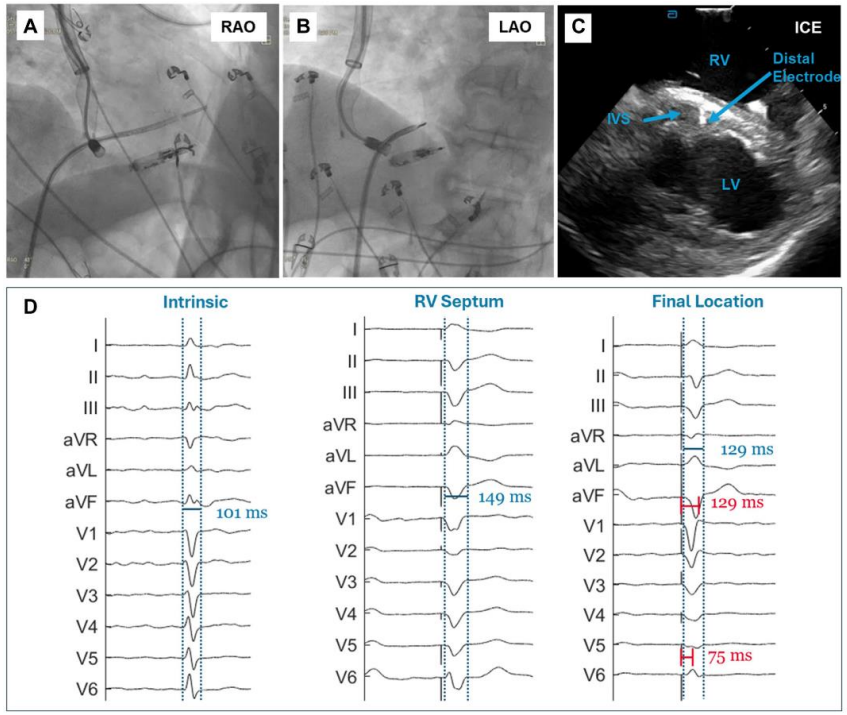


Le graal : le pacemaker leadless-CSP

Figure 1
Schematic diagram of the LP_{CSP} leadless pacemaker.

First-in-human study of a leadless pacemaker system for left bundle branch area pacing

Vivek Y. Reddy, MD,[1,2] Devi G. Nair, MD, FHRS,[3] Shephal K. Doshi, MD,[4] Rahul N. Doshi, MD, FHRS,[5] Milan Chovanec, MD,[2] Leonard Ganz, MD, FHRS,[6] Leyla Sabet, PhD,[6] Chunlan Jiang, PhD,[6] Petr Neuzil, MD, PhD[2]



Merci de votre attention !

Essais randomisés contrôlés en cours

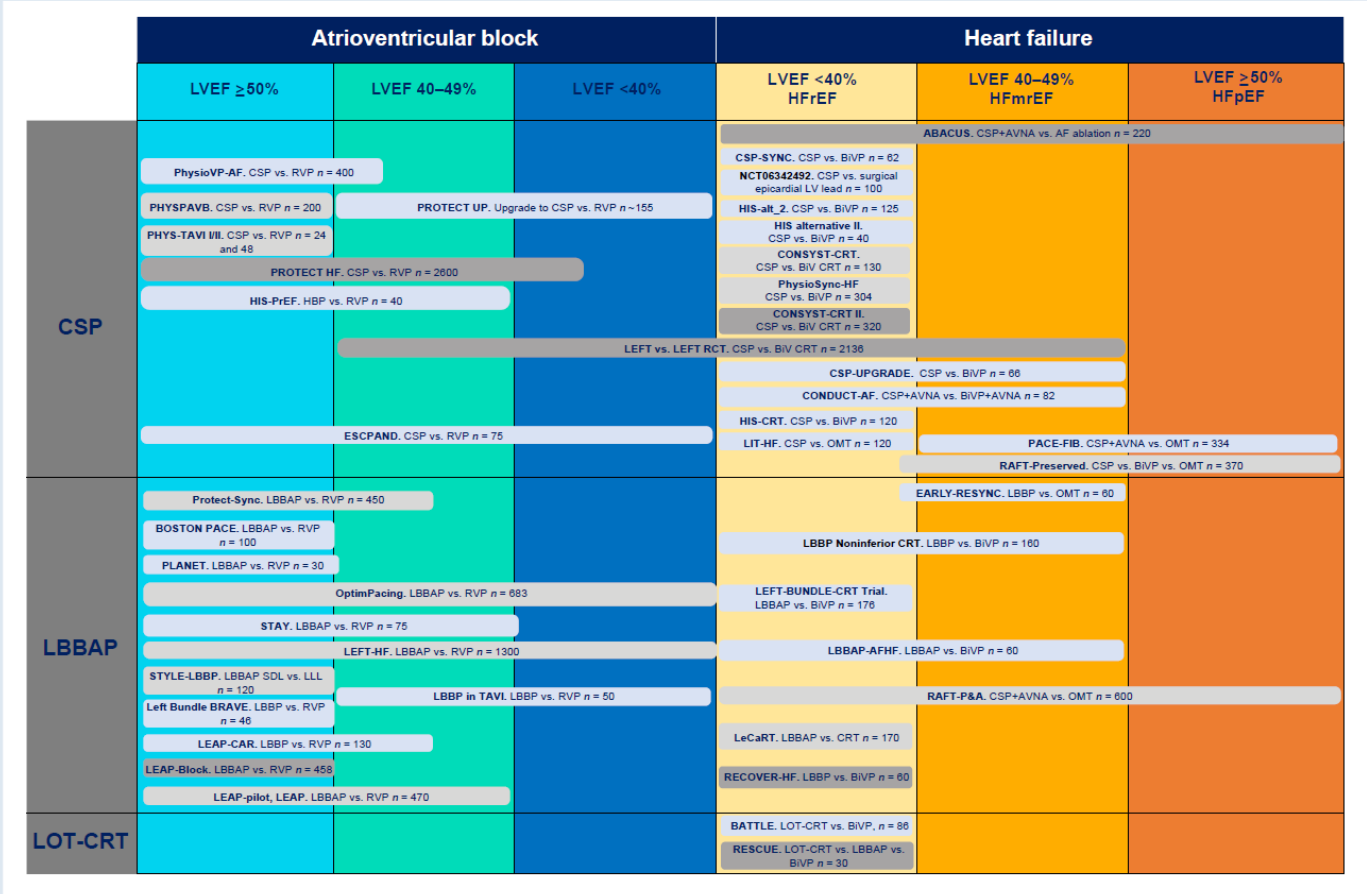


Figure 11 Summary of ongoing RCTs on conduction system pacing. The background colours of the study names represent different types of study endpoints: light grey indicates soft endpoints, dark grey indicates hard endpoints, and medium grey indicates a combination of soft and hard endpoints. AF, atrial fibrillation; AVNA, atrioventricular node ablation; BiVP, biventricular pacing; CRT, cardiac resynchronization therapy; CSP, conduction system pacing; HBP, His bundle pacing; HFrEF, heart failure with reduced ejection fraction; HFmrEF, heart failure with mid-range ejection fraction; HFprEF, heart failure with preserved ejection fraction; LBBAP, left bundle branch area pacing; LBBP, left bundle branch pacing; LOT-CRT, left bundle branch-optimized cardiac resynchronization therapy; LV, left ventricle; LVEF, left ventricular ejection fraction; OMT, optimal medical therapy; RVP, right ventricular pacing.