ESC European Society of Cardiology
Europace (2023) **25**, 1237–1248
https://doi.org/10.1093/europace/euad044

EHRA DOCUMENT

EHRA clinical consensus statement on conduction system pacing implantation: executive summary. Endorsed by the Asia-Pacific Heart Rhythm Society (APHRS), Canadian Heart Rhythm Society (CHRS) and Latin-American Heart Rhythm Society (LAHRS)

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Received 3 February 2023; accepted after revision 3 February 2023

Abstract

Conduction system pacing (CSP) has emerged as a more physiological alternative to right ventricular pacing and is also being used in selected cases for cardiac resynchronization therapy. His bundle pacing was first introduced over two decades ago and its use has risen over the last years with the advent of tools which have facilitated implantation. Left bundle branch area pacing is more recent but its adoption is growing fast due to a wider target area and excellent electrical parameters. Nevertheless, as with any intervention, proper technique is a prerequisite for safe and effective delivery of therapy. This document aims to standardize the procedure and to provide a framework for physicians who wish to start CSP implantation, or who wish to improve their technique. A synopsis is provided in this print edition of *EP-Europace*. The full document may be consulted online, and a 'Key Messages' App can be downloaded from the EHRA website.

Keywords Conduction system pacing • His bundle pacing • Left bundle branch area pacing • Device implantation

Abbreviations

A	atrial
AVN	atrioventricular node
COI	current of injury
CS	coronary sinus
CSP	conduction system pacing
DSP	deep septal pacing
ECG	electrocardiogram
EGM	electrogram
HBP	His bundle pacing
iso	isoelectric
LAO	left anterior oblique
LAFP	left anterior fascicle pacing

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LBBAP	left bundle branch area pacing
LBB	left bundle branch
LBBP	left bundle branch pacing
LFP	left fascicular pacing
LPFP	left posterior fascicle pacing
LSFP	left septal fascicle pacing
LVSP	left ventricular septal pacing
LV	left ventricular
RAO	right anterior oblique
RBB	right bundle branch
RBBP	right bundle branch pacing
RV	right ventricle
RWPT	R-wave peak time
SDL	stylet-driven lead

Definitions

The different entities of CSP, and related forms of pacing, are shown in *Figure 1*.

Conduction system pacing: direct activation of the conduction system of the heart by the pacing stimulus.

His bundle pacing: direct capture of the atrioventricular bundle with activation of all of its fibres. The pacing lead may be located proximally on the atrial aspect of the tricuspid valve, or distally on the ventricular aspect. The His bundle potential to QRS interval at the pacing site is usually ≥ 35 ms In some patients, the distal His bundle may be paced from deep in the septum.

Right bundle branch pacing: direct capture of the proximal RBB (usually observed when the distal His bundle is targeted).[2] Criteria are outlined in. Direct capture of the distal RBB is rare.

Left bundle branch pacing: capture of the pre-divisional LBB with activation of all of its fascicles. Pacing lead position deep in the interventricular septum, ∼1–2 cm from the distal His bundle potential (or the tricuspid valve summit), LBB potential to QRS interval 34–25 ms, normal QRS axis and fulfilled criteria for conduction system capture.

Left fascicular pacing: capture of one of the LBB fascicles or its distal arborization. Potential to QRS interval < 25 ms, often with an paced QRS axis, with presence of criteria for conduction system capture. Includes LAFP, LSPF and LPFP.

Left ventricular septal pacing: capture of the left side of the interventricular septum (basal to mid-septal area) without direct activation of the left conduction system. Terminal R-wave in V1 and absence of criteria for conduction system capture. The left-sided conduction system may be rapidly engaged retrogradely despite lack of direct capture.

Left bundle branch area pacing: capture of the subendocardial area on the left side of the interventricular septum, with or without simultaneous conduction system capture (terminal R-wave in lead V1 may be absent in some cases) and includes LBBP, LFP and LVSP.

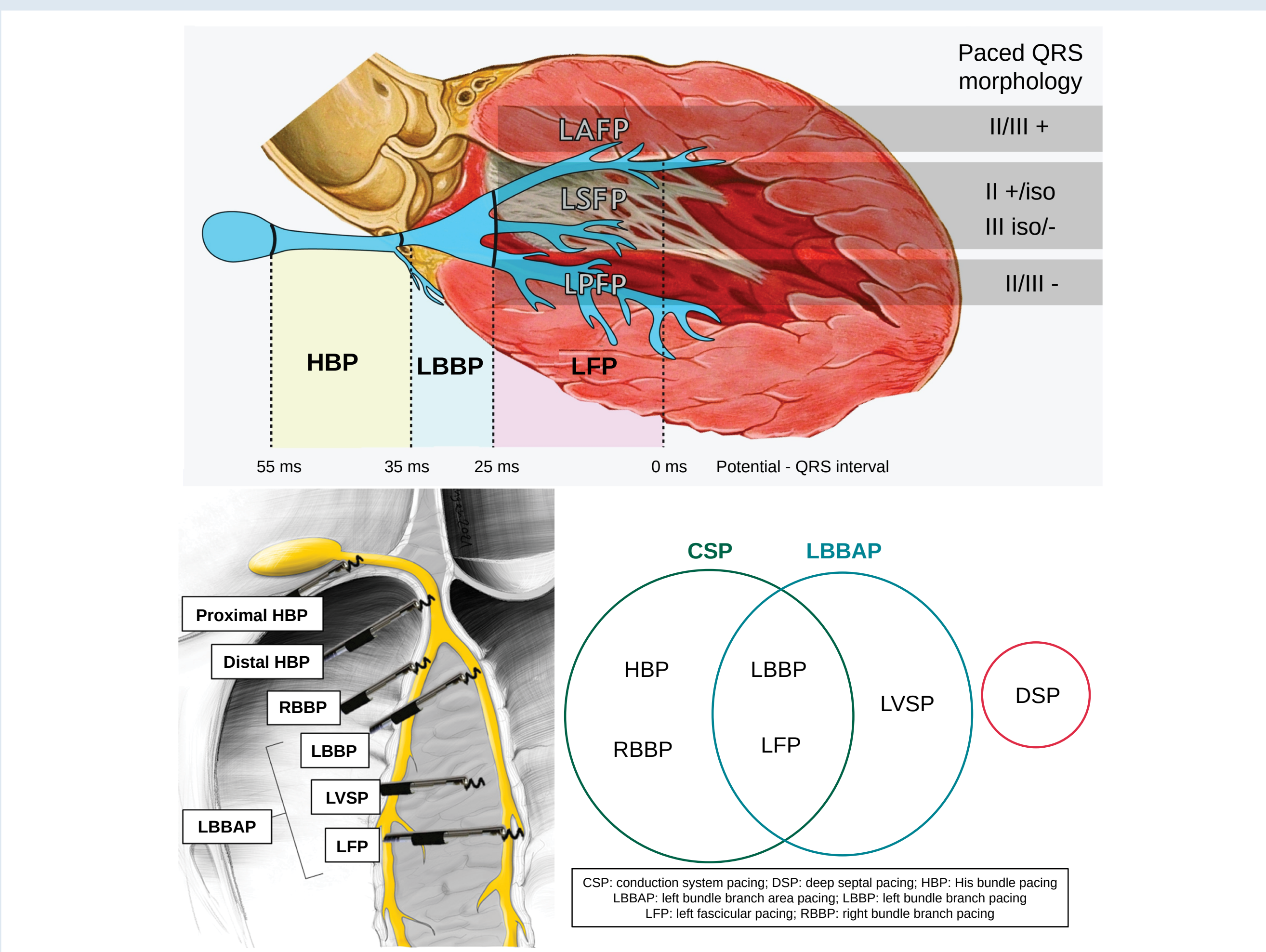

Figure 1 Synopsis of CSP and related pacing modalities. Modified with permission from Filip Plesinger and from Jastrzebski *et al.*[1]

Deep septal pacing: lead positioned deep in the septum but does not reach the left ventricular subendocardial area. Differentiated from LBBAP by lack of terminal R-wave in lead V1 *and* no features of left conduction system capture.

His bundle pacing lead implantation

Key steps

(1) Locate the His bundle using unipolar mapping by the pacing lead in the RAO 20–30° view. Ideally, a sharp near-field His potential is visualized, with absent or small far-field atrial electrogram and a larger ventricular electrogram. Locating the His bundle by pacemapping at 5 V/1 ms is useful if a His potential is not visualized.
(2) Screw the lead while stabilizing the guiding catheter. Torque build-up should be felt, with rebound upon release of the lead (the number of lead rotations is variable).
(3) Check the morphology of the His potential, which ideally should show a COI and/or a negative potential. Presence of His capture may be briefly checked (e.g. at 5 and 2 V/0.5 ms).
(4) Withdraw the guiding catheter by 5–8 cm to expose the lead.
(5) Test for stability by gently pulling, or pushing the lead to give a 'U' form with two additional rotations of the lead to test for changes in capture threshold or reduction His potential amplitude.
(6) Perform threshold testing by carefully analyzing the ECG for His capture (see *Figure* 2). A His threshold of ≤ 1.5 V/0.5 ms is optimal but up to 2.5 V @0.5 ms may be acceptable. Presence of COI may initially result in high thresholds, which may improve over the following minutes. Bipolar sensing should ideally be > 2 mV (low sensing thresholds may require a backup ventricular lead for sensing).
(7) Implant additional leads as required.
(8) Check His thresholds again before slitting.
(9) Slit guiding catheter.
(10) Adjust lead slack and perform final threshold test.

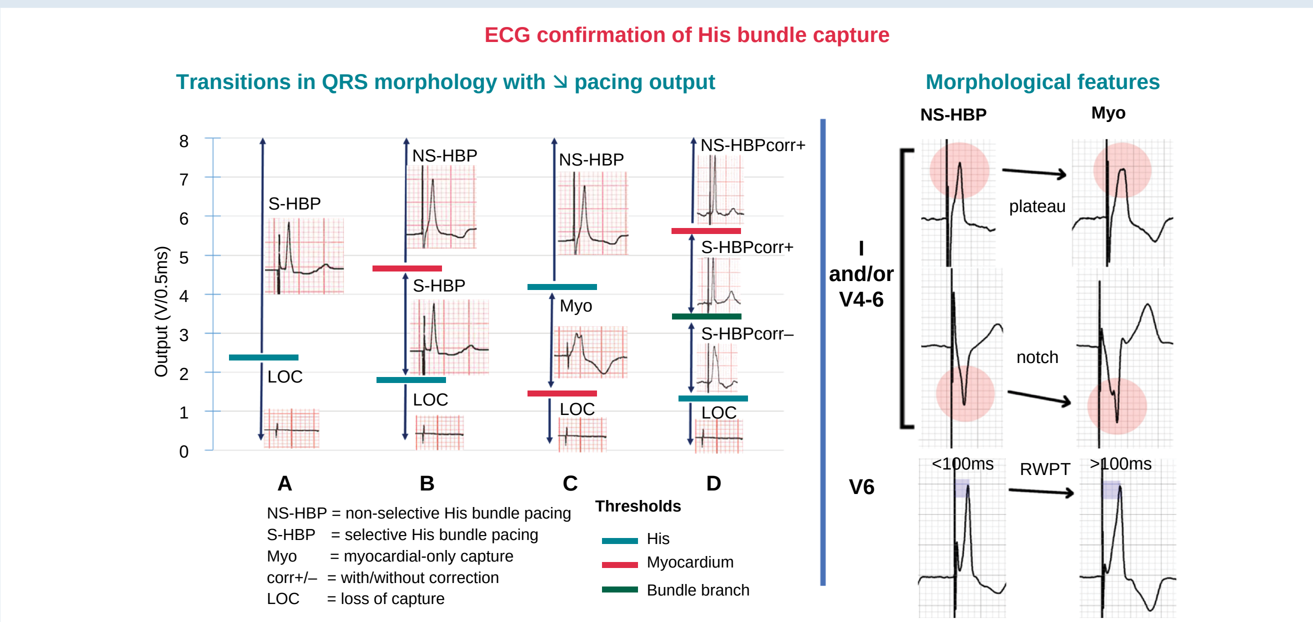

Figure 2 ECG transitions with decrementing pacing output, and morphological features to diagnose his bundle capture. Adapted with permission from Burri *et al.*[3]

Left bundle branch area pacing

Key steps

(1) Locate the His bundle or the tricuspid annulus summit in the RAO 20–30° fluoroscopic view using unipolar sensing by the pacing lead. Alternatively, contrast injection via the guiding catheter may be used to delineate the tricuspid valve. Store reference image.

(2) Advance the guiding catheter into the right ventricle at 15–20 mm from the His bundle towards the apex (see *Figure 3*). The lead should be kept within the guiding catheter to avoid snagging of the screw on the tricuspid valve. Apply slight counterclockwise torque to the guiding catheter to position it against the septum and push out the lead by a few millimetres. Presence of a COI of the ventricular signal indicates good contact.

(3) Pacemap, and adjust lead position if necessary, aiming at discordant QRS in leads II (predominantly positive or equiphasic) and III (equiphasic or predominantly/completely negative). A W' pattern with a notch at the nadir of V1 may be observed (although this is not mandatory).

(4) Shift to the LAO 30–40° view. The guiding catheter should orient the lead at 10–40° superiorly to the horizontal plane in order to be perpendicular to the septal curve (see *Figure 4*). Contrast injection via the guiding catheter may optionally be performed to delineate the septum. Adjust orientation if necessary.

(5) Rapidly rotate the lead body to screw in the lead, while applying some forward push and maintaining the guiding catheter in position. Continuous screening allows to check coaxial orientation between the guiding catheter and the lead and evaluates progression of the lead in the septum. Ideally, lead depth should be monitored by continuous pacing performed while screwing the lead (via the stylet of SDLs, or using a tool designed for this purpose for lumenless leads). Entanglement, drill, or screwdriver effects should be recognized (*Figure 5*). Lead depth should be monitored using the parameters shown in *Table 1* and screwing should be continued utile the paced QRS morphology is satisfactory (see *Figure 6*). Lead course may also be checked in RAO.

(6) Test lead stability by gently pulling on the lead, or by withdrawing the delivery catheter and pushing the lead to form an α-shaped loop.

(7) Perform threshold tests.

(8) Implant additional leads if required

(9) Check paced QRS morphology and thresholds before slitting the guiding catheter

(10) Adjust slack and perform a final check of paced QRS morphology and thresholds.

Device configurations for CSP lead connections are shown in *Figure 7*.

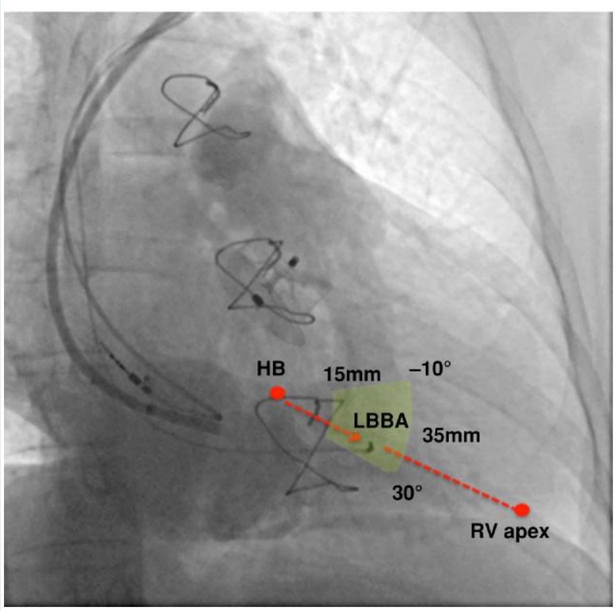

Figure 3 Insertion site for LBBA pacing. In a 30° RAO view, contrast is injected through a sheath delineating right atrial and ventricular anatomy as well as tricuspid valve leaflets. The summit of the tricuspid annulus indicates the approximate His bundle position. The red arrow indicates an imaginary line that connects the tricuspid annulus summit/His bundle with the RV apex, which serves as a guide for placing the lead. Successful pacing sites can be localized within a sector (indicated in yellow) located 15–35 mm away from the tricuspid annulus summit and at an angle of −10° to 30°, as described by Liu *et al.*[16]

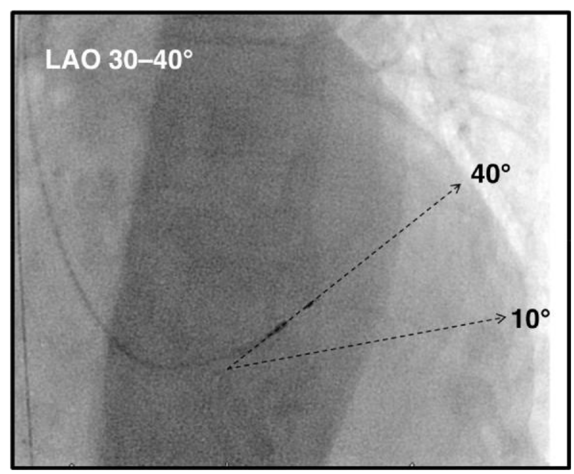

Figure 4 Left panel: LAO view for orienting the lead 10–40° (most often 20–30°) with respect to the horizontal plane for perpendicular septal penetration.

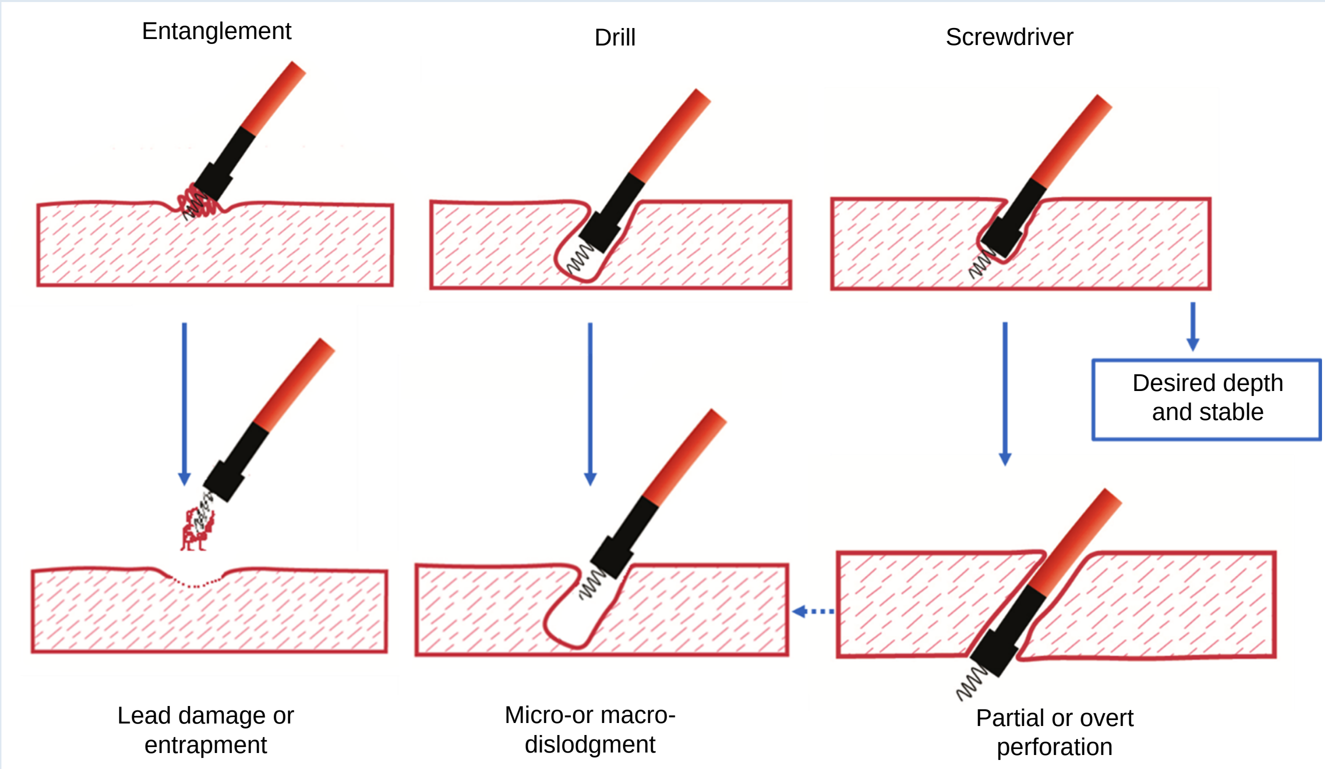

Figure 5 Lead behaviour during penetration of the septum with LBBAP. Both drill and screwdriver effects can result in perforation.

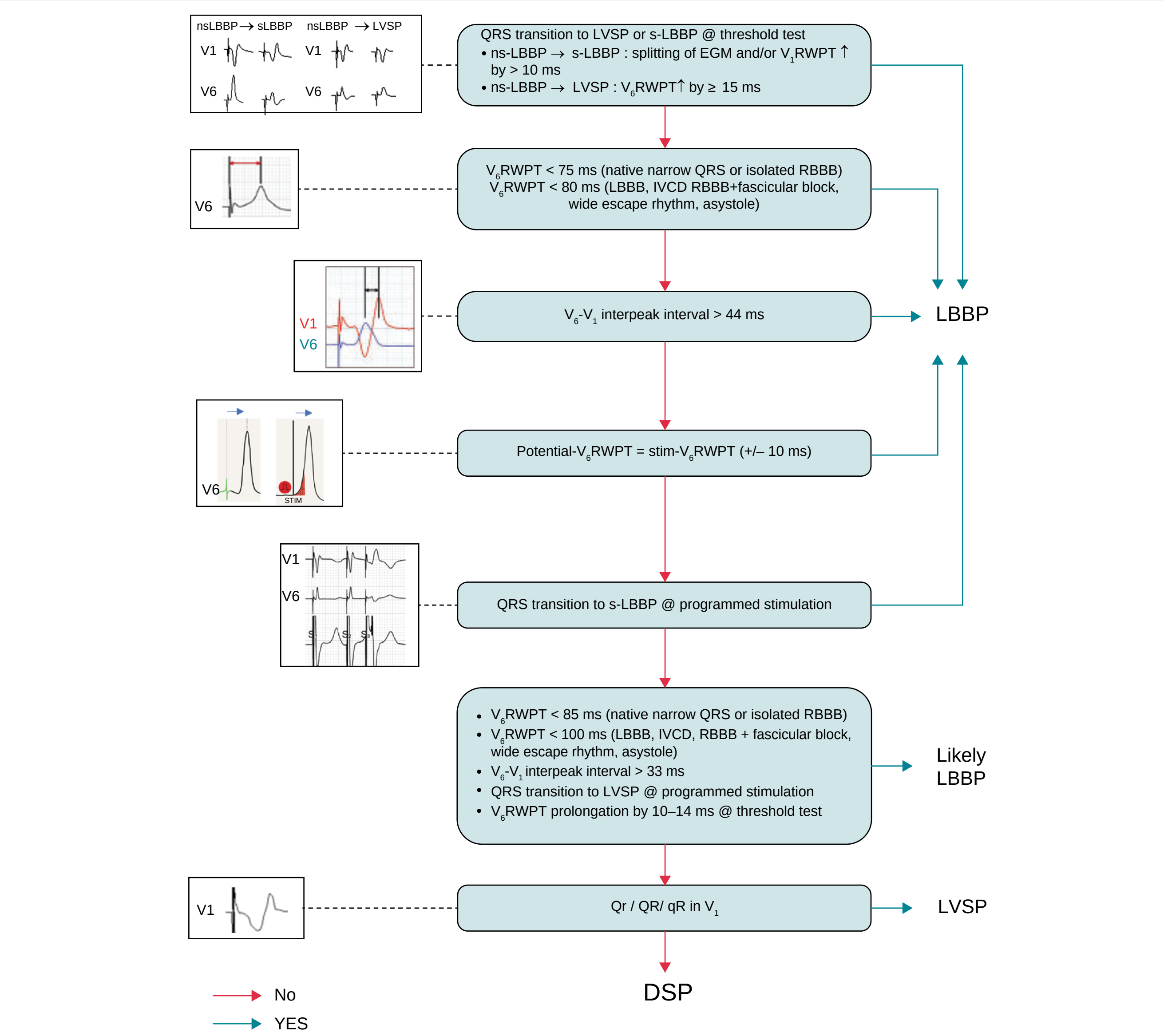

Figure 6 Algorithm for confirming conduction system capture with LBBAP. Some of the steps may be skipped according to operator preference, experience or feasibility to perform particular measurements/maneuvers.

Table 1 Parameters to monitor LBBAP lead depth

(1)	Lead progression with continuous fluoroscopy in LAO 30–40°
(2)	Unipolar paced QRS morphology
(3)	Fixation (template) beat morphology
(4)	Unipolar pacing impedance (care if ~ 500 Ω or Δ > 200 Ω)
(5)	COI amplitude (care if ~ 5 mV)
(6)	Visualization of a LBB/fascicular potential
(7)	Contrast injection via delivery sheath to delineate the septum
(8)	COI and/or cathodal capture from ring electrode
(9)	Hinge point of the lead

Table 2 Complications with left bundle branch area pacing and their incidences

Per-operative complications
Septal perforation (0.0–14.1%) [3,5,19–27]
Right bundle branch block (19.9% with 6.3% permanent)[19]
Complete heart block (9.4% acute with 2.6% permanent)[19]
Intra-operative lead dislodgment (3.0%)[22]
Acute coronary syndrome (0.4–0.7%)[3,28]
Coronary artery fistula (1.4–2.0%)[23,26]
Coronary vein fistula/injury[27,29]
Septal hematoma[30]
Helix damage/fracture (0.8–5.0%)[26,31,32]
Post-operative complications
Delayed septal perforation (0.1–0.3%)[3,26,33,34]
Worsening tricuspid regurgitation (7.3–32.6%-)[19,22,35,36]
Lead dislodgment (0.3–1.5%) [3,19,20,24,27,33,37,38]
Rise in threshold by >1 V (0.3–1.8%)[3,19,20,27,37]
Loss of LBB capture (0.3–11.5%)[3,19,27]

Table 3 Advantages and limitations of HBP and of LBBAP

HBP	LBBAP
Advantages	***Advantages***
Maximum electrical synchrony.	Large target area.
Endpoints well defined for successful His capture.	Correction of more distal conduction disease.
Extractability has been demonstrated.	Low capture thresholds.
Relatively good mid-term evidence for safety and efficacy.	Good sensing parameters.
Avoids crossing the tricuspid valve when implanted on the atrial aspect of the annulus).	Consistent backup myocardial capture (in addition by anodal capture by the ring electrode).
Some evidence of medium and long-term lead extraction.[52,53]	No requirement for backup pacing leads.
	AV nodal ablation without risk of compromising lead function
Disadvantages/limitations	***Disadvantages/limitations***
Small target area.	Conduction tissue capture may be difficult to demonstrate in some cases.
Capture thresholds may be high.	Requirement of digital callipers (i.e. electrophysiology recording system) for measuring parameters of conduction system capture.
Sensing issues (atrial and His oversensing, ventricular undersensing).	Less electrical synchrony compared to HBP, especially in patients with normal baseline QRS).
Limited to correction of proximal conduction block only.	Complications specific to transseptal route (septal perforation, lesions to coronary vessels, septal hematoma etc.).
Risk if distal conduction block develops over follow-up.	Tricuspid regurgitation.[19,22,35]
High (up to 11%[54]) requirement for lead revision.	May be challenging in patients with septal scar.
Backup ventricular leads may be indicated in specific situations.	Limited (but growing) evidence for safety and efficacy.
Complex programming in case of backup leads	Long-term extractability needs to be demonstrated.
Risk of compromising lead function with AV node ablation.[55–57]	

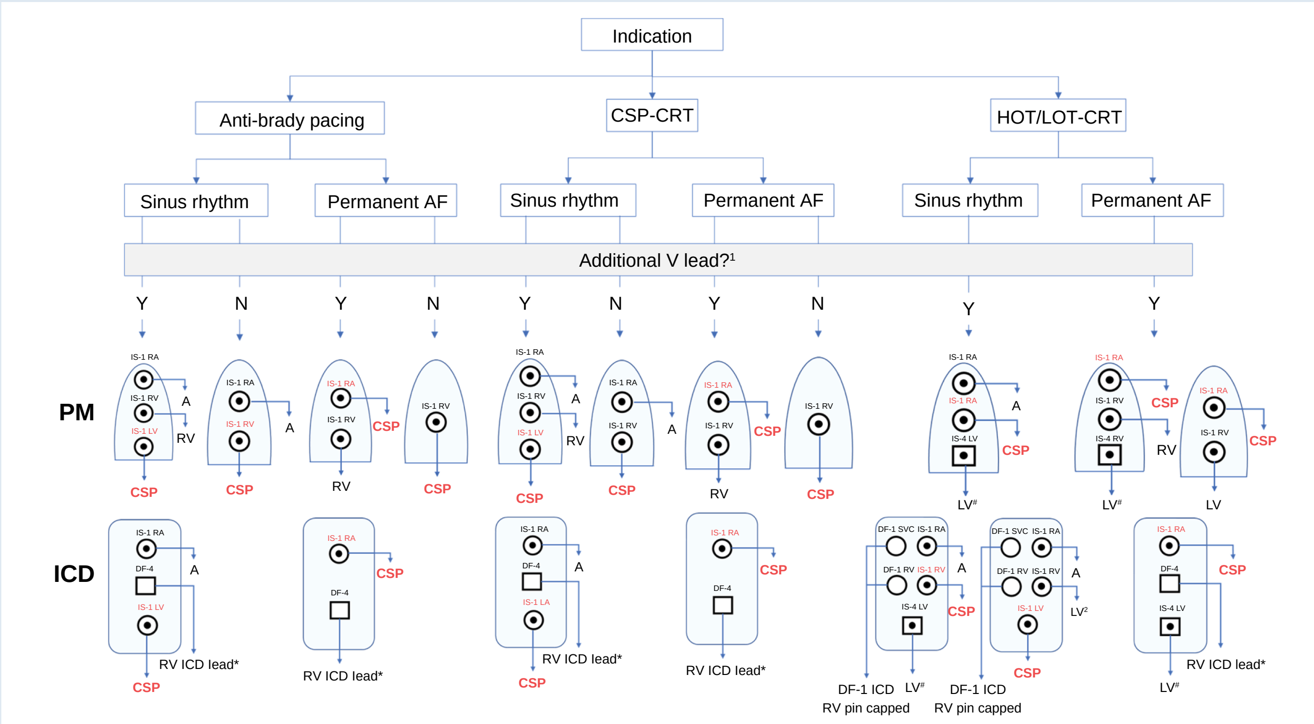

Figure 7 Device configuration for CSP according to device indication, underlying rhythm (i.e. requirement for an atrial lead), presence on an additional ventricular lead. In all cases with a CSP lead plugged to the RV port, adequate sensing must be ensured. Not shown here are additional configurations with Y-adapters.[1] Additional ventricular lead may be indicated for ICD therapy, backup pacing, adequate ventricular sensing, or CRT optimization.[2] The LV lead is plugged to the RV port in case the CSP lead does not provide proper sensing (atrial or His potential oversensing and ventricular undersensing are issues that may be encountered with HBP). * DF-1 ICD lead may also be used; # IS-1 LV lead may also be used.

Funding

None declared.

Conflict of interest: H.B. has received speaker honoraria, consulting fees or institutional fellowship/research support from Abbot, Biotronik, Boston Scientific, Medtronic and Microport. C. I. has received speaker honoraria or consulting fees from Abbot, Biotronik, Boston Scientific, Medtronic and Microport, as well as research support from MicroPort. O.C. has received speaker honoraria and consulting fees from Biotronik, Boston Scientific and Medtronic K.C. has received speaker honoraria and consulting fees from Biotronik, Boston Scientific and Medtronic. J.D.P. reports speaker honoraria and consultancy fees from Medtronic, Biotronik, Abbott and Boston Scientific. J.J. reports support from Medtronic (investigator-initiated external research grant) and Boston Scientific (consulting). K.V. has received speaker honoraria, consulting fees or institutional fellowship/research support from Abbot, Boston Scientific, Medtronic and Microport. P.V. has the following declarations: Medtronic—Speaker, consultant, research and fellowship support; Abbott—consultant; Biotronik, Boston Scientific—honoraria; Patent- HBP delivery tool. Z.W. has received speaker honoraria, consulting fees or institutional fellowship/research support from Abbot, Boston Scientific, Medtronic. The other authors have not reported any disclosures.

Advices tables

Strength of Advice	Symbol
Clinical advice, based on robust published evidence	
Clinical advice, based on consensus of the writing group	
May be appropriate, based on published evidence	
May be appropriate, based on consensus of the writing group	
Areas of uncertainty	
STRENGTH OF EVIDENCE	**Abbreviation**
Randomized controlled trials	RCT
Meta-analysis	META
Observational studies	OBS
Expert opinion	OPN

Advices Table 1 General considerations for CSP implantation

General Considerations	Evidence	Strength
Advice TO DO		
12-lead ECG should be recorded during conduction system pacing implantation, ideally using an electrophysiology recording system for simultaneous endocardial and ECG signals.	OPN	
Endocavitary electrograms with minimally filtered signals showing current of injury should be displayed.[4,5]	OPN	
May be Appropriate TO DO		
If an EP recording system is not available, use of a 12-lead ECG with a pacing system analyzer for mapping endocardial signals may be used.[3]	OBS	
Advice NOT TO DO		
CSP implantation should not be performed without a minimum display of ECG leads I, II, III, V1 and V5 or V6.	OPN	

Advices Table 2 HBP

His Bundle Pacing	Evidence	Strength
Advice TO DO		
His bundle capture should always be confirmed at implantation and follow-up, using validated criteria[7–10] such as transitions in QRS morphology with decrementing output / programmed stimulation and comparison of intervals from His potential and from pacing stimulus to V6 R-wave peak.	OBS	
Screwing of the lead should be continued until significant torque buildup is felt to ensure lead stability	OPN	
Lead stability should be routinely assessed[11]	OBS	
May Be Appropriate TO DO		
In case of infranodal conduction delay or block, pacing at 400ms or shorter cycle length showing 1:1 conduction without aberration should be tested.[12]	OBS	
Lead rotations should be pursued until a His current of injury or deep negative morphology is observed, which predicts good electrical parameters.[13,14]	OBS	
Unipolar His capture thresholds should be <2.5 V / 0.5ms but should ideally aim for $\leq$ 1.5V / 0.5ms. Bipolar sensing amplitude should be >2 mV (without atrial/His oversensing)	OPN	
In the interest of safety, a backup ventricular lead can be useful in specific situations such as poor sensing, pacemaker-dependency, high-grade AVB, infranodal block, high pacing threshold and planned AVJ ablation.	OPN	
Areas of uncertainty		
Both selective as well as non-selective HBP are acceptable and probably have similar outcome although non-selective HBP provides the safety of ventricular backup capture and higher sensing amplitudes.[15–18]	OBS	

Advice Table 3 LBBAP

Left bundle branch area pacing	
Advice TO DO	
Lead depth should be monitored using different techniques such as fluoroscopy, unipolar paced QRS morphology and impedance, fixation/template beat morphology,[39,40] presence of a fascicular potential,[41] current of injury amplitude,[4,5] contrast injection via the delivery catheter and capture by the ring electrode.	OBS
It is appropriate to evaluate and report presence or absence of conduction system capture using validated criteria[42–44] such as transition in QRS morphology with decrementing output/programmed stimulation, V6RWPT, V6-V1 interpeak interval, comparison of intervals from intrinsic potential and from pacing stimulus to V6 R-wave peak.	OBS
Lead entanglement at the insertion site (characterized by torque build-up) or a "drill" effect during screwing (recognized by lack of lead progression on fluoroscopy and by pace-mapping despite lead rotations) should be recognized to avoid lead damage and dislodgement respectively.[45]	OBS
Acceptable thresholds for LBBAP capture are <1.5 V @ 0.5 ms (ideally<1 V @ 0.5 ms) and bipolar sensing should ideally be >4 mV.	OPN
May be appropriate TO DO	
Lead insertion site is evaluated based upon fluoroscopy in the 20-30° right anterior oblique view at 15-35mm from the His bundle / tricuspid annulus and using pacemapping.[1]	OBS
The lead can be screwed into the interventricular septum at an angle of 10-40° superior to the horizontal plane in the left anterior oblique 30-40° view.	OBS
Advice NOT TO DO	
In case of perforation of the septum, the lead should be repositioned at a new site and not simply withdrawn slightly.	OPN
Areas of uncertainty	
It is unclear at this point if conduction system capture with left bundle branch area pacing is necessary to achieve good clinical outcome.[46–51]	OBS

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