

Pacing of the specialized His-Purkinje conduction system: ‘back to the future’

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KEYWORDS

Conduction system pacing;
His-Purkinje system;
His-bundle pacing;
Left bundle branch area
pacing;
Ultra-high-frequency
electrocardiogram

The conduction system of the human heart is composed of specialized cardiomyocytes that initiate and propagate the electric impulse with consequent rhythmic and synchronized contraction of the atria and ventricles, resulting in the normal cardiac cycle. Although the His-Purkinje system (HPS) was already described more than a century ago, there has been a recent resurgence of conduction system pacing (CSP), where pacing leads are positioned in the His bundle region and left bundle branch area to provide physiological cardiac activation as alternatives to the unnatural myocardial stimulation obtained with conventional right ventricular and biventricular pacing. In this review, we describe the fundamental anatomical and pathophysiological aspects of the specialized HPS along with the CSP technique’s nuts and bolts to highlight its potential benefits in everyday clinical practice.

Introduction

Cardiac pacing is the mainstay therapy for treating symptomatic bradyarrhythmias, and right ventricular pacing (RVP) has been the primary strategy for decades to improve survival and quality of life in this setting.¹ Nonetheless, it was already shown by pivotal trials in the early 2000s that the detrimental effect of chronic RVP leads to adverse remodelling and left ventricular (LV) systolic function, especially in patients with pre-existing cardiomyopathies.²

In the quest for an alternative pacing site, pacing the specialized conduction system emerged as the reliable alternative to preserve the physiological ventricular

activation without the unfavourable effects of chronic RVP.³ His-bundle pacing (HBP) and, more recently, left bundle branch area pacing (LBBAP) showed promising effects on LV function and clinical outcomes in small randomized clinical trials and observational studies in patients with bradycardia and heart failure (HF) candidates to resynchronization therapy.^{4,5} However, technical challenges, namely chronic lead issues with HBP and lack of information on the long-term performance and safety of LBBAP, still need to be addressed to give CSP first-line indications in guidelines and widespread physiological pacing use in routine clinical practice.¹

In this review, we aim to describe the assumptions behind conduction system pacing (CSP), the technicalities of the implanting procedure, and the targeted follow-up to underline the present controversies and prospects of this technique.

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Anatomy of the His-Purkinje system

Sir Wilhelm His Jr was the first to report in 1893 a sheltered strand of specialized myocardium connecting the atria and ventricles, but only in 1906, Tawara conveyed the electrical properties of these histologically distinct cells that conduct impulses from the atrioventricular (AV) node to the His bundle (HB) with its ventricular terminations.^{3,6} He observed that the cell type in the HB becomes predominantly Purkinje type, with longitudinal orientation and separated by collagenous septa, furnishing the anatomical basis for the theory of longitudinal dissociation in the HB postulated by Kaufmann and Rothberger in 1919. The HB can be divided anatomically into three portions: penetrating bundle of His, which penetrates the fibrous membranous septum or the central fibrous body close to the mitral ring and runs anteriorly and inferiorly; non-branching portion, which runs a variable course on the crest of the muscular ventricular septum, and branching portion closely related to the aortic ring, which branches off to give the left bundle branch (LBB) and right bundle branch (RBB). The site of penetration of HB was found in an atrial location distant from the septal leaflet insertion of the hinge point of the tricuspid valve (TV) septal leaflet in 53.7%, at the level of the hinge point in 31.7%, and below the level of hinge point within the ventricular component of the membranous septum in 14.6% of the cases (Figure 1).^{3,6}

The left bundle branch (LBB) always arises inferior to the membranous septum between the right and non-coronary aortic cusp. The LBB is a thick band-like structure, takes an immediate subendocardial course on the left side of the septum, and typically divides in a trifascicular pattern into septal, anterior, and posterior fascicles. The septal branch supplies the mid-septal area, most commonly arising from the main trunk. Still, it can also emerge from the anterior or posterior fascicle or a complex plexus of network originating from the anterior and posterior fascicle. The left anterior fascicle is a thin and long structure that traverses towards the anterolateral papillary muscle. The left posterior fascicle is a thick, broad, short structure that transits towards the posteromedial papillary muscle. The fascicles radiate into an extensive network of Purkinje fibres with intricately connections that supply the LV endocardium.^{3,6}

Pathophysiological properties of the His-Purkinje system

The whole electrical activation sequence of the human heart was first described by Durrer back in the 1970s as assessed by mapping the LV activation using intramural electrodes, proving the specialized features of the His-Purkinje system (HPS) and the tri-fascicular nature of the LBB.⁷ The HPS starts the ventricular activation that

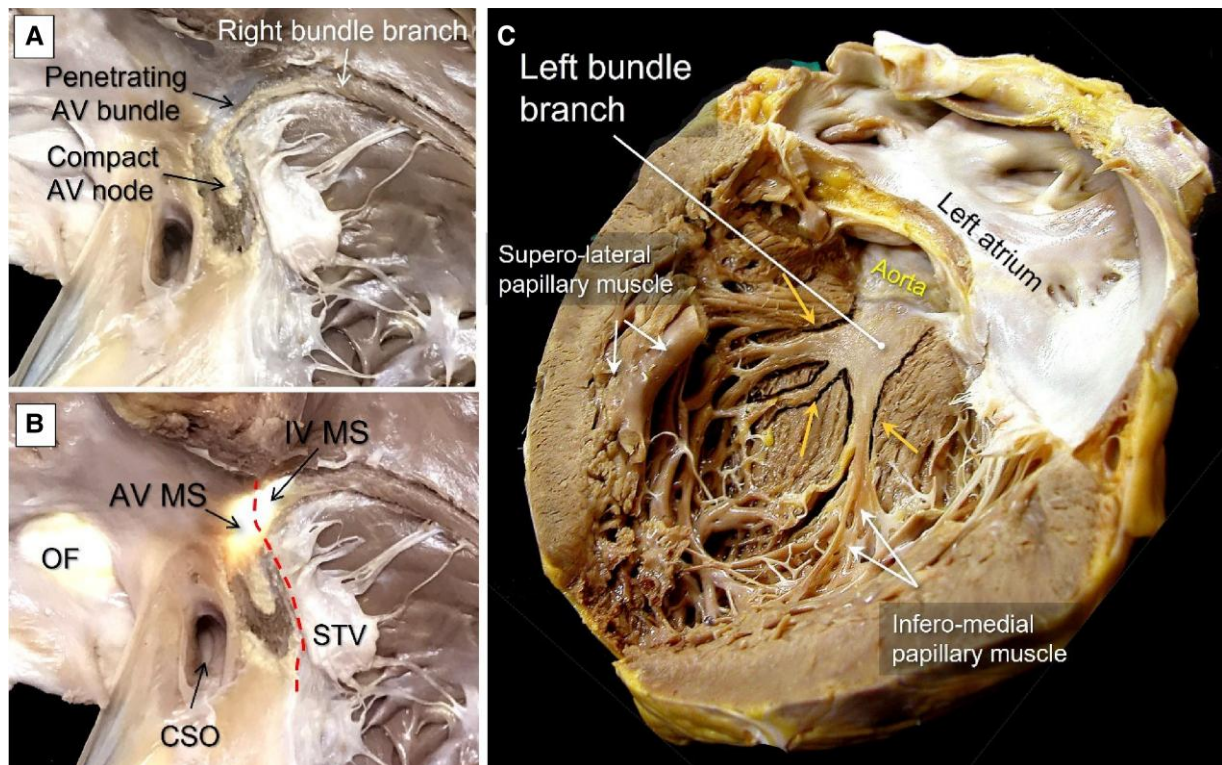


Figure 1 (A and B) Gross dissections of the human atrioventricular conduction axis relative to the triangle of Koch, revealing the position of the atrioventricular node and the penetrating bundle relative to the hinge line of the septal leaflet of the tricuspid valve. Note the dividing line between the atrioventricular component of the membranous septum and the interventricular component of the membranous septum. The penetrating atrioventricular bundle enters the atrioventricular component of the membranous septum encircled by the fibrous tissue of the central fibrous body. (C) The left bundle branch arises between the right and non-coronary sinus. Note that we have highlighted in dark colour the limits of the endocardial position of the main trunk and its three fascicles towards the papillary muscles. CSO, coronary sinus orifice; OF, oval fossa.

arises from the LBB in endocardial areas on the left interventricular septum (IVS) surface, then proceeds from the left to right septum towards the apicobasal direction of the ventricles through the presence of Purkinje system ramifications within the endocardium.³

Damages within the HPS, therefore, can lead to conduction disturbances, namely, bundle branch block (BBB), and potentially life-threatening bradycardias.

The potential benefit from CSP appeared promising as it was observed that chronic RVP increased the risk of adverse cardiac remodelling—the so-called pacing-induced cardiomyopathy (PICM). But also, BVP, despite its proven clinical benefit in HF patients, is a non-physiological pacing modality that restores ventricular synchronization with a wavefront from the LV epicardium with only a modest reduction in QRS duration and LV activation time (LVAT).³ In this regard, repristinating the integrity function of the specialized HPS is the appealing paradigm for CSP with the scope to maintain the physiological ventricular action or restore cardiac synchronization.

Some physiological properties of the HB should be considered when performing CSP. First, the concept of longitudinal dissociation of HB suggested that BBBs are often caused by conduction block/delay within fibres in the HB already predestinated to either the LBB or RBB, hence correctable by pacing distally to that site.⁸ More recently, Upadhyay *et al.*⁸ performed invasive mapping of the HB and LV septum, reporting that LBB blocks in the proximal conduction system (within the HB and proximal LBB) could be circumvented by CSP.⁸ However, CSP resulted in incomplete correction in the case of intact His-Purkinje conduction when the delayed LV activation was secondary to the distal conduction system or myocardial tissue disease. In this latter case, a more completed resynchronization seems achievable from combining pacing the HPS with epicardial pacing of LV through BVP as observed in preliminary studies on His-optimized CRT (HOT-CRT) and LBBAP-optimized CRT (LOT-CRT).

Other proposed but unproven mechanisms that may be involved in the corrective effects of CSP on BBBs include the virtual electrode effect, the transverse connections between the bundles, and the retrograde activation of HB and the RBB with LBBAP.³

How to perform His-bundle pacing

The first permanent HBP lead implantation was reported in 2000, with 70% of success in patients with permanent atrial fibrillation (AF) candidates for AV junction ablation (AVJA).^{9,10}

His-bundle pacing is technically challenged by the narrow target zone surrounded by electrically inert fibrous tissue. This translates into potential troubleshooting issues with a high risk for HB lead revision at follow-up.

At the beginning of the HBP era, the procedures were performed by reshaping conventional stylets, using mapping catheters from the groin to identify the target HB region, and with the additional implantation of a backup lead in the RV. However, the implanting technique was subsequently refined when in 2014, Sharma and colleagues described 80% of the success of permanent HB lead implantation with the adoption of a lumen-less (LLL) electrically actively exposed helix lead delivered through pre-shaped sheaths and without the need for mapping or bailout catheters.^{9,10}

At that time, the lead most commonly used for HBP was the Medtronic SelectSecure model 3830 pacing lead (4.1 Fr, isodiametric, lumen less, exposed helix) delivered via a 9 Fr deflectable sheath (SelectSite C304, Medtronic) or via a 7 Fr fixed curve sheath (C315HIS, Medtronic). The step-by-step approach to implantation is described in the following paragraphs.¹⁰ After obtaining venous access, the sheath is delivered across the tricuspid annulus. Next, the His-bundle region is mapped with the HB lead from the ventricular to the atrial aspect with rotation and withdrawal of the sheath body.^{9,10} Mapping for the His potential is generally performed in unipolar configuration with electrograms (EGMs) visualized by an electrophysiological recording system (at 100 mm/s sweep speed) or by a pacing system analyzer (PSA). Mapping could be assisted by standard fluoroscopic views, particularly in the left anterior oblique (LAO) view, to ensure that the lead is orthogonal to the septal surface. Counterclockwise rotation of the sheath results in infero-posterior movement (usually towards the septum), whereas clockwise rotation results in anterosuperior movement. The best target site is that with a clear His potential, an appropriate R-wave to P-wave amplitude (at least 2:1) and HB capture threshold <1.5 V at 0.5 ms. When HB potentials are not recorded, pace mapping is generally performed. When HB capture is confirmed instead, the lead is screwed to achieve final fixation. The most critical issue is then to confirm His-bundle capture by analysing changes in paced QRS morphology/duration either with differential voltage output or with programmed electrical stimulation (PES) as described later in this review (see the ‘How to confirm conduction system capture’ section) (*Figure 2*). In challenging situations where it is not easy to record HB potential or in cases of complex anatomy (e.g. significantly dilated atria), the use of a deflectable sheath (SelectSite C304-HIS, Medtronic) or a sheath-in-sheath approach (fixed C315His inside a right-sided multipurpose outer coronary sinus sheath) has been described as potential alternatives.¹¹

More recently, other vendors have commercialized dedicated sheaths to perform HBP: Biotronik launched a pre-shaped sheath (Selectra 3D) available with three lengths and different curves depending on the width of the primary curve (40, 55, or 65 mm); Boston Scientific launched the Site Selective Pacing Catheters with four available pre-shaped curves (SSPC1-4, Models 9181-9184); Abbott launched the Agilis HisPro steerable catheter with two distal tip electrodes capable of sensing intracardiac EGMs and pace. In these latter cases, the delivering sheaths can be used with the conventional stylet-driven extendable-helix leads (SDLs).¹² Stylet-driven extendable-helix lead adaptation for HBP generally requires practical preventive manoeuvres to avoid partial unwinding of the extendable helix, as manual rotations applied on the outer body of the lead could cause the inner coil not to follow the external lead body rotations. Initial studies describe the comparable acute success of LLL and SDL for HBP.¹² However, future studies should assess the potential differences in the long-term performance of the two pacing leads.

How to perform left bundle branch area pacing

The feasibility of deep septal pacing was first described by Mafi-Rad and colleagues using a custom-designed lead in

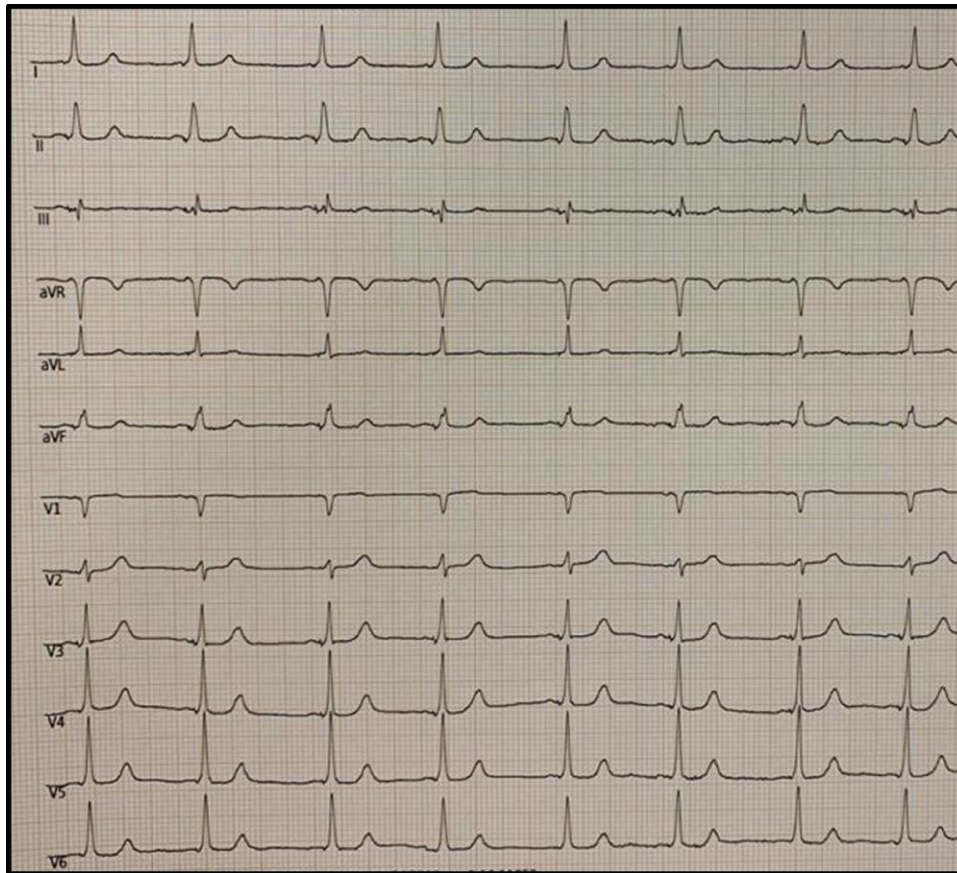


Figure 2 An example of non-selective His-bundle pacing capture on a 12-lead electrocardiogram in a patient with baseline narrow QRS.

the mid-distal septum and providing acute haemodynamic benefits over RVP.¹³ Nonetheless, it was in 2017, when Huang pioneered the LBBAP technique by implanting a lead deep in the RV septum distally to HB and capturing the LBB in a patient with HF and LBBB, achieving a more stable pacing position and better pacing parameters. Furthermore, a significant narrowing of the QRS duration and improvement in LV ejection fraction (LVEF), and functional class over a 1-year follow-up was observed.¹³ Since then, LBBAP has rapidly emerged as a viable alternative pacing opportunity with a high success rate of 80-97%.¹⁴ However, its electro-mechanical aspects and long-term performance still need to be ascertained in adequate large randomized clinical trials to widen its application in the standard clinical practice.

Left bundle branch area pacing can be performed using a SelectSecure3830 pacing lead (Medtronic), which has recently received food and drug administration (FDA) approval for this indication, delivered via a 7 Fr fixed curve sheath (C315HIS, Medtronic) or 9 Fr deflectable sheath (SelectSite C304-HIS, Medtronic).¹⁵

The steps of the implanting procedure can be resumed as follows.¹⁵ The distal His-bundle potential is annotated in the right anterior oblique (RAO) fluoroscopic view using the delivery sheath and the 3830 lead. If the His-bundle potential is difficult to identify, the tricuspid annulus can be used as a reference or an RV angiogram can be quite helpful. The sheath is turned clockwise and gently

advanced 1.5-2 cm into the ventricle towards the RV basal septum. Unipolar tip pacing is performed to identify the site where the paced QRS shows a 'W' morphology in lead V1 with an intermediate QRS axis. The pacing lead is then screwed deep inside the interventricular septum with rapid rotations until the paced QRS morphology resembles the RBB conduction delay or RBBB pattern in lead V1 (qR or rsR'). As the lead penetrates inside the septum, the impedance gradually rises until a drop is observed in the case of perforation. Ponnusamy *et al.*¹⁶ reported a decline in unipolar pacing impedance until values <450 Ω in the case of septal perforation (sensitivity 100%, specificity 96.4%). An LBB potential can often be appreciated (generally in the case of preserved LBB conduction). Electrophysiological criteria are adopted to confirm LBBAP capture (see the 'How to confirm conduction system capture' section).

A study by Jastrzębski *et al.*¹⁷ suggested an alternative way to perform LBBAP using an uninterrupted pacing-while-screwing technique until RBBB-paced QRS morphology or RBBB ventricular extrasystoles (fixation beats) appear. Fixation beats are triggered by the lead when approaching (irritating) the LBB area. Although they are not diagnostic for LBB capture, lead screwing should be stopped when they appear to avoid inadvertent septal perforations (Figure 3).¹⁷

Finally, a contrast injection through the side port of the sheath can be performed in the LAO fluoroscopic view to

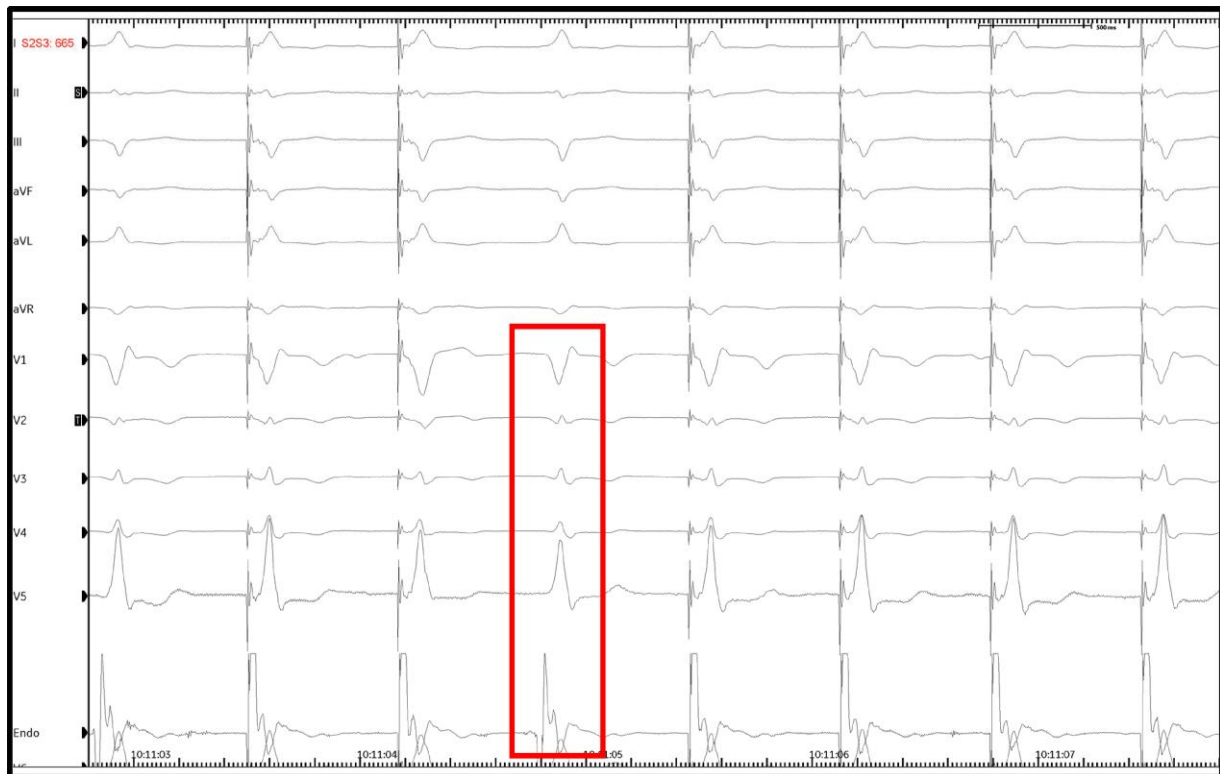


Figure 3 An example of fixation beat during lead deployment and continuous pacing-while-screwing technique. Fixations beats are premature ventricular complexes generated during lead deployment with morphology changing from QS to qR in lead V1 as the lead reaches the left bundle branch area.

delineate the RV septal wall and confirm the lead depth in the IVS. Moreover, knowing the distance between the screw tip and the ring electrode (i.e. 10.8 mm for LLL), the evidence of anodal ring capture can provide a rough estimate of lead depth into the septum.

How to confirm conduction system capture

The fundamental of a successful CSP procedure is to demonstrate the output-dependent morphologic QRS changes as an expression of the capture exclusive of the specialized conduction system (selective capture) or the coupled capture of HPS with myocardial tissue (non-selective capture).^{3,11,16}

His-bundle pacing is considered selective (S-HBP) when the surface electrocardiogram (ECG) has an isoelectric interval between the pacing spike and the onset of a QRS complex identical to the native conduction and a discrete local EGM on unipolar recordings. Non-selective His-bundle pacing is considered when there is a delta wave between the pacing spike and the QRS complex and no discrete local EGM on unipolar recordings.

Selective His-bundle pacing can also be confirmed using device EGMs. A near-field EGM with a time to peak of more than 40 ms, a near-field initial positive deflection after the pacing spike, or a far-field QRS duration of <120 ms was consistent with S-HBP. The absence of HB capture at implant or a loss of HB capture during follow-up (septal capture only) can be confirmed by QRS notching or slurring in ECG leads I, V1, V4-V6, and a prolonged R-wave peak time (RWPT) of >110 ms in V6.

In the case of LBBAP, to differentiate non-selective (NS)-LBBP and S-LBBP from LV septal pacing (LSVP) is mandatory to prove LBB capture.^{10,18}

Conventionally, LBB capture is therefore considered when ≥ 3 of the following validated criteria are met: (i) paced morphology of RBBB pattern; (ii) presence of LBB potential; (iii) LV activation time: measured from the stimulus to the peak of the R-wave in V5/V6 short and constant at high (5 V) and low (1 V) output pacing; (iv) demonstration of non-selective to selective capture or non-selective to septal capture transition during threshold testing. S-LBB: Stim-QRS latency and discrete local EGM separate from stimulus artefact seen. NS-LBB: No stim-QRS latency and no discrete local EGM separate from stimulus artefact; (v) evidence for direct LBB capture. Additional electrophysiological manoeuvres and criteria can be embraced to discriminate between LBB and LVSP.

Jastrzębski *et al.*¹⁹ described the usefulness of PES to differentiate LBB capture vs. LV septal myocardial capture based on their differential effective refractory periods. Response to premature beats is classified as myocardial when the paced QRS morphology changes to myocardial-only capture (broader QRS, with a slur/notch/plateau and with change in amplitude/polarity in several leads), or S-LBB when the paced QRS morphology transforms to a typical RBB morphology preceded by a latency. They also described other surrogated electrocardiographic ('physiology based') criteria to confirm LBB capture. They demonstrated that the capture of LBB in patients with non-LBBB rhythm could be confirmed when the

paced V6 RWPT, measured from the QRS onset, equals the native non-paced V6 RWPT or when the stim to V6 RWPT equals the LBB potential to the native non-paced V6 RWPT. In patients with LBBB at baseline, the capture of the LBB can be confirmed when the paced V6 RWPT is shorter than the native V6 intrinsic deflection by more than the trans-septal conduction time.

More recently, the V6-V1 interpeak interval has been proposed as a novel criterion for diagnosing LBB area capture.²⁰ Distinct patterns of right ventricular and LV activation translating into different combinations of RWPT in V1 and V6 can result from various combinations of direct capture/non-capture of the septal myocardium and the LBB. Consequently, the V6-V1 interpeak interval could differentiate the three types of LBBAP capture. In that study, the optimal value of the V6-V1 interval value for the differentiation between ns-LBB and LVS capture was 33 ms with a specificity of 100% for the diagnosis of LBB capture obtained with a cut-off value of >44 ms. However, all these surrogated criteria for LBB capture need to be validated in future larger studies.

Assessment of ventricular synchrony beyond the QRS complex: the ultra-high-frequency ECG

The paradigm of CRT is to correct the electro-mechanical dyssynchrony determined by BBBs, especially in HF patients with LBBB. However, QRS width and morphology are indirect measures of cardiac dyssynchrony and give only partial information on ventricular activation.

Ultra-high-frequency (150-1000 Hz) 14-lead ECG technique (UHF-ECG) is a novel electrical heart activity imaging method. It provides data from the depolarization of heart chambers at frequencies above 100 Hz and displays the ventricular activation sequence from standard chest V1-V8 leads in <5 min.²¹ Because of attenuation in the perimyocardial tissue, the signal generated on a particular lead displays electrical activity from nearby, rather than remote, myocardial tissue. Ultra-high-frequency signals of myocardial activation are converted to UHF-ECG maps, which show the depolarization pattern of both ventricles, and time differences in their activation can be analysed. The technique has already demonstrated its clinical validity in the sub-analysis of the Multicenter Automatic Defibrillator Implantation-Cardiac Resynchronization Therapy trial.²¹

For each precordial lead (V1-V8), the amplitude envelopes are computed in 16 frequency bands 150-250, 200-300, 250-350, ... 850-950, and 900-1000 Hz using the Hilbert transformation. The broad-band QRS complex (UHF-QRS) is then transmitted as the average of the 16 normalized median amplitude envelopes. UHF-QRS complexes from all precordial leads can be displayed as a colour map reflecting ventricular depolarization along the direction of the precordial leads. Two numerical parameters are computed with UHF-ECG: ventricular e-DYS and single lead local activation duration (Vxd). e-DYS is calculated as the maximal time difference between local activation times of leads V1-V8, using the centre of mass of the signals. This calculation is based on the idea that the UHF-QRS signal originates in depolarization wavefront. Its morphology is the sum of stronger depolarization signals from adjacent areas to the electrode and weaker

signals from remote regions. Vxd is defined as the duration of the UHF-QRS complex at half the maximum peak magnitude of ECG lead x. In this way, we assume that Vxd indicates the velocity of conduction underneath a specific electrode, low Vxd values point to high apparent conduction velocities, presumably due to the contribution of the intrinsic conduction system and high Vxd values to a non-homogeneous substrate (e.g. the presence of a scar). Vd is the mean of all Vxd values and measures the average depolarization propagation duration.²¹

There are already data published that show the potential of UHF-ECG.^{21,22} A small study showed that BVP reduces e-DYS but not Vd. It can be explained by the reduction in ventricular dyssynchrony without influencing the mean conduction velocity during the BVP. In contrast, HBP reduced both e-DYS and Vd, the latter pointing to the contribution of the rapid conduction system to electrical resynchronization. A more detailed study showed no significant differences between selective and non-selective HBP in e-DYS and Vd in patients with narrow QRS. The distinction between LBBP and LVSP was investigated in subsequent research. It was shown that both LVSP and LBBP are less physiological than HBP. Although the LVSP preserves the same level of interventricular dyssynchrony as HBP, it worsens the pattern of LV activation. On the other hand, the LV activation is during the nsLBBP the same as during the HBP, but at the cost of increasing the interventricular dyssynchrony.²²

Future studies are needed to show the different impacts on the biventricular synchronization of CSP compared with BVP. In this complex scenario, UHF-ECG with additional informative dyssynchrony parameters and ventricular activation patterns may be helpful to improve patient selection, guide device programming, and optimize response to CRT.

Device follow-up of conduction system pacing

The success of CSP also depends on proper device programming and troubleshooting at follow-up. Since the devices currently available are not explicitly designed for CSP, the knowledge of device settings is essential to guarantee the safety and the greatest benefit from CSP.²³

First, it is crucial to indicate in the device notes and patient card the eventual presence of a pacing lead in HB position or LBBA and to which port has been connected (especially in the case of conduction system optimized-CRT: HOT-CRT and LOT-CRT). The follow-up with CSP could require more frequent checking than with standard pacing, especially for HBP, when the loss of HBP capture with the consequent need for lead revision is reported in up to 11% of the cases.

When performing device follow-up, a contemporary acquisition of 12-lead ECG is crucial to ascertain the various type of captures during threshold tests.

The pin of the generator to which the CSP lead is connected depends upon the baseline rhythm, the presence of an RV backup lead, and the indication for pacing (bradycardia vs. CRT). In the case of a CSP lead connected to the atrial port, the DDIR is preferred in most instances. This is because, in the case of DDD mode, a premature ventricular beat may be sensed in the atrial channel and undersensed in the ventricular channel triggering ventricular pacing in the vulnerable period.

With HBP, sensing values are lower than traditional RV pacing values, and ventricular undersensing may occur due to lower EGM amplitude. Of note, oversensing of atrial or HB potentials may also happen and potentially lead to asystole in the case of total AV block. Therefore, setting a fixed sensitivity is preferred over automatic sensitivity, which can result in oversensing phenomena. However, sensing is generally not an issue with LBBAP as the R-wave amplitude is high as traditional RV pacing without the interference of atrial or HB potentials.

Unipolar pacing (not available in most ICDs) is generally set on the CSP lead. The unmistakable appearance of the pacing spike on surface ECG may also facilitate recognizing the different types of capture and distinguishing them from the intrinsic rhythm.

The capture threshold test should always be performed in the VVI mode in order to have an entirely paced QRS and avoid pseudo-fusions. As different thresholds can be observed, capture management algorithms should be switched off or activated only if clinically required after providing stable and accurate measurements.

In the case of sinus rhythm with residual spontaneous AV conduction, it is crucial to optimize the AV delay. In the case of HBP, the HV interval should be considered and subtracted from the desired AV delay. For LBBAP, the pacing stimulus should be synchronized with the intrinsic RBB activation.

When a CSP lead is connected to an LV port of a CRT generator, the RV lead serves for ventricular sensing, backup pacing, or delivering therapy (in the case of ICD). Accordingly, sequential pacing can be programmed with the first activation from the CSP lead (LV channel) followed by RV pacing after a settable V-V. Instead, pacing from only the CSP lead may be established to avoid unnecessary battery drain once stable thresholds with the CSP have been verified.

Automatic AV and VV optimization algorithms should be generally inactivated as they are not designed for CSP and may result in altered device functioning or unnecessary battery depletion. Finally, in ICDs with a CSP lead in the atrial port, all dual-chamber discrimination algorithms should be inactivated, as only single-chamber discriminators can be safely used.²³

Conduction system pacing: the present and the future

Conduction system pacing in the state of HBP and LBBAP appears as the best pacing modality reproducing the normal evolutionary LV activation and preventing the adverse consequences of RVP.²⁴ Furthermore, CSP has already shown its positive potential in small pilot randomized clinical trials and several observational studies with high success rates, translating into remarkable clinical impact and echocardiographic outcomes in different clinical scenarios such as advanced AV blocks, chronic AF, and patient candidates for CRT.¹⁴

His-bundle pacing is the ideal form of physiological pacing, but technical challenges at implantation and during follow-up suffuse its wide adoption. The controversial electro-mechanical implications of LBBP (especially vs. LVSP) and the long-term performance and safety/extractability of a lead placed deep in the septum are instead the main barriers for LBBAP that require further answers in

dedicated clinical trials.¹³ Therefore, according to the available data, recommendations for LBBAP are not formulated at this stage from current pacing guidelines, whereas guidelines reserve an alternative role for HBP in CRT candidates in whom coronary sinus lead implantation is unsuccessful or in patients with AV blocks and LVEF > 40% who have an expected ventricular pacing burden >20%.¹

Moreover, in patients treated with HBP, guidelines suggest the implantation of an RV lead as a 'backup' for pacing in specific situations (e.g. pacemaker dependency, high-grade AVB, intranodal block, high pacing threshold, planned AVJ ablation).¹ Data from large RCTs with long-term follow-ups are eagerly awaited to prove the CSP's superiority over the standard of care represented by RVP and BVP. The current indications will probably need to be revised once more solid evidence is published. Finally, the acknowledgement of CSP's past and current limitations reflect the obstacles that are customary in the early evolution of a new technology and might be optimistically overcome by the engineering of specific tools for the implanting procedures (sheaths and leads) and new dedicated device functions in the future.

Funding

No funding has been used to complete this work.

Conflict of interest: All authors have reported that they have no relationships relevant to the contents of this review to disclose.

Data availability

This manuscript is a review article therefore there are no original data to share. We have properly referenced all the cited studies within the review.

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