Conduction System Pacing

Should We Pace the His Bundle or the Left Bundle Branch Area?

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Abstract

His bundle pacing is the most physiological form of pacing as it replicates the patient's natural ventricular activation. Its adoption has significantly grown over the last years. However, the technique has several limitations, including suboptimal thresholds. Left bundle branch area pacing has been introduced more recently and has gained much interest as it also delivers physiological pacing but with more favorable electrical parameters. However, there are also several unresolved issues with this technique. This article compares these strategies and highlights their advantages and disadvantages to provide guidance on which technique to select for a specific patient.

Keywords: Left bundle branch pacing; His bundle pacing; conduction system pacing, HOT-CRT, LOT-CRT

Introduction

Conduction system pacing (CSP) is gaining mainstream practice for providing a more physiological alternative to right ventricular pacing (RVP) and, in some instances, as an alternative or in addition to biventricular pacing for cardiac resynchronization therapy (CRT). Currently, the following two main implantation sites are targeted: the His bundle and left bundle branch area, which includes the left bundle branch, the left-sided fascicles, and the left ventricular septum [1]. Proximal right bundle branch pacing has also been described and usually results from targeting the distal His bundle region [2, 3].

In a survey conducted by the European Heart Rhythm Association (EHRA) in 31 countries, CSP is anticipated to predominate over RVP and biventricular pacing in subsequent years [4]. The growth in European sales of the Medtronic 3830 lead (Minnesota, MN, USA), which is the most frequently used lead for CSP, illustrates the uptake of this technique (fig. 1). Furthermore, the EHRA survey indicated that left bundle branch areal pacing (LBBAP) was generally preferred over His bundle branch pacing (HBP) due to more successful implantation and better electrical parameters, which was also reported in a separate survey of CSP adopters [5]. Nevertheless, LBBAP is not frequently successful, may not provide the same extent of ventricular synchrony compared with HBP, and can have extractability-related concerns. Therefore, which technique should be preferred remains debated. This review aimed to describe and compare these techniques.

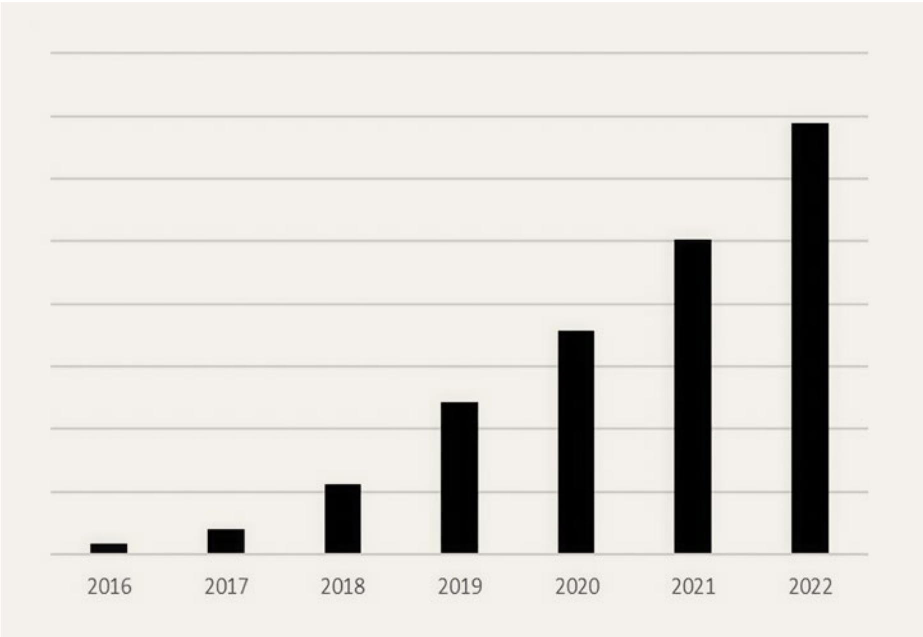

Figure 1: Evolution of sales in Europe for the Medtronic 3830 lead, most frequently used for conduction system pacing and reflecting the adoption of this pacing modality. Data is provided by Medtronic (actual numbers are not shown).

History

In 1967, temporary HBP was first described in a canine model [6] and in 1970 in a human model [7]. It was not until 2000 that permanent HBP in humans using standard pacing leads was published [8]. This study was a groundbreaking milestone in the development of HBP; however, the technique was not widely adopted because of technical challenges with long procedural durations and high thresholds. Furthermore, the device industry at that time mainly focused on developing tools for facilitating lead implantation in coronary sinus tributaries for CRT. Two decades ago, the Medtronic 3830 lumenless catheter-delivered lead was introduced and was initially intended for selective site pacing of the interventricular septum. This lead, used with a deflectable delivery catheter, was adopted for HBP implantation and improved success rates compared with traditional stylet-driven leads [9]. In 2017, the lead gained magnetic resonance imaging labeling, and its use for HBP was significantly facilitated by the advent of a three-dimensional (3D)-shaped C315-His delivery catheter. Along with an increasing number of publications on HBP, social media with the Twitter hashtag #Dontdisthehis significantly contributed to the uptake of HBP since 2017 [10]. In 2017, HBP was first introduced in Switzerland at our center [11], with >250 cases since then, and continues to be performed to date.

In 2017, Huang et al. [12] from China published the first case report on left bundle branch pacing (LBBP) using the 3830 lead in a patient with heart failure and complete left bundle branch block and showed procedural success with low pacing output and positive clinical outcomes at the 1-year follow-up. Subsequently, LBBAP gained widespread adoption mainly because of excellent electrical parameters. In 2020, LBBAP was introduced in Switzerland at our center, with approximately 400 cases implanted since then.

Tools and Technique for Implantation

An EHRA consensus document on CSP implantation comprehensively describing the implantation technique has been recently published and serves to standardize HBP and LBBAP implantation [1]. CSP requires recording a 12-lead electrocardiogram (ECG) and the ideal use of an electrophysiology recording system with digital calipers for measuring intervals for LBBAP. The same hardware is used for both techniques. The Medtronic 3830 lead, which is a 4.1-F lumenless fixed-helix lead that is delivered using either a fixed (C315-His) or deflectable (C304-His) 3D-shaped catheter with a posterior distal curve that greatly facilitates lead positioning on the target site, is the most frequently used lead (fig. 2). Moreover, stylet-driven leads are used for HBP and especially for LBBAP in clinical practice [4, 13]. Although the leads are commercialized and used in routine clinical practice since years, their labeling for CSP is at different stages [14].

Briefly, the pacing lead is used to map the His signal in a unipolar mode under fluoroscopic guidance. Pace mapping may also be used for locating the His bundle and the LBBAP lead insertion site. HBP leads may be implanted either on the atrial or the ventricular aspects of the His bundle [15]. For LBBAP, the His bundle is mapped and serves as a reference point, or, alternatively, the tricuspid annulus is identified by endocavitary signals or contrast injection. The sheath and lead are subsequently advanced approximately 2 cm toward the right ventricle apex. The zone for HBP is limited and needs to be very precisely targeted, whereas successful implant for LBBAP can be achieved over a much larger area.

These are the challenges with HBP implantation: locating the His bundle, fixating the lead to achieve a stable position, and obtaining acceptable sensing and capture thresholds. The main difficulties with LBBAP include: penetration of the interventricular septum (which may be fibrotic), achieving a stable lead position ("drilling" of the lead creates a tunnel and may result in micro/macro-dislodgement), and obtaining physiological ECG parameters. His capture confirmation is frequently relatively straightforward and can be performed by observing the transition in QRS morphology with decrementing pacing output [16], whereas LBBAP conduction system capture identification is more challenging and usually requires the measurement of specific intervals using digital calipers at high sweep speed on an electrophysiology recording system [1, 17].

In an observational study [18], Hua et al. compared the pacing and electrophysiological characteristics between HBP and LBBAP in 251 patients undergoing CSP implantation for bradycardia indications (125 and 126 patients in the HBP and LBBP groups, respectively). Success rates did not significantly differ between the two procedures (87.2% HBP, 91.3% LBBAP); however, procedure and fluoroscopic durations as well as sensing and capture thresholds were significantly better with LBBAP. A recent report by Tan et al. showed similar results [19]. Two meta-analyses comparing the pacing parameters of LBBAP with HBP at implantation and follow-up indicated that capture thresholds are significantly lower and sensed R-waves are higher with shorter procedural and fluoroscopic durations with LBBAP [20, 21].

Patients with infranodal atrioventricular (AV) block have lower implant success rates of HBP than those with nodal block (76% vs 93%, respectively, according to a single-center series) [22]. For LBBAP, patients with heart failure have lower implantation success rates than those with bradycardia indications (82% vs 92%, respectively, according to the MELOS [multicentre European left bundle branch area pacing outcomes study] registry) [23]. This finding is probably caused by the septal scar in these patients that makes penetrating the septum difficult [24].

The learning curve for HBP flattens after approximately 50–60 cases [25], whereas that for LBBAP is less well described but is probably similar.

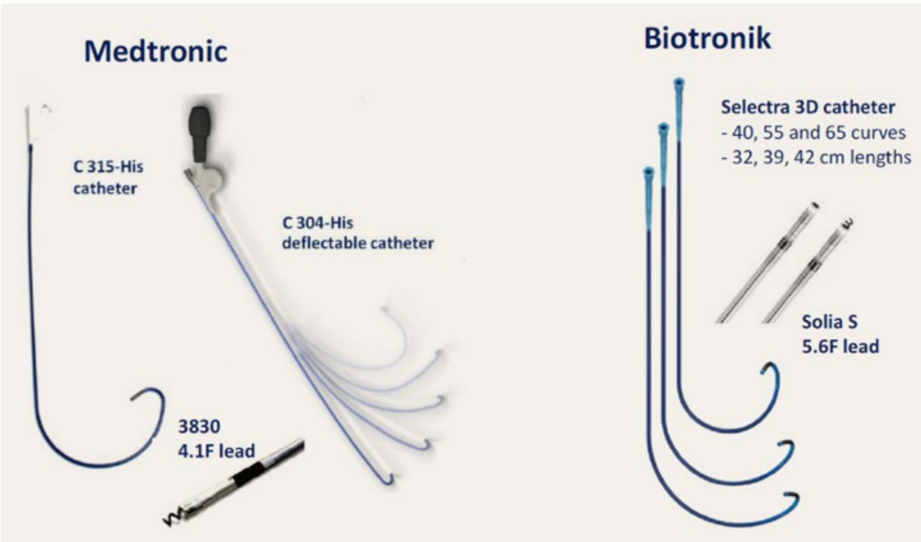

Figure 2: Tools most frequently used for conduction system pacing. (A) Medtronic lumenless 3830 lead and delivery catheters. (B) Biotronik stylet-driven lead and delivery catheters.

Impact on Ventricular Synchrony, Ejection Fraction, and Clinical Outcomes

A meta-analysis of seven nonrandomized studies reported that HBP resulted in a narrower QRS duration than LBBAP (fig. 3) [21]. In an acute study comparing biventricular pacing, HBP, and LBBP using ECG imaging and hemodynamic measurements in 19 patients, HBP resulted in the greatest reduction in the total ventricular activation time (owing to delayed right ventricular activation with LBBAP) [26]. Left ventricular activation time and acute hemodynamic improvement were comparable between the pacing modes and superior to biventricular pacing. In another acute intra-patient comparison between HBP and LBBP in 20 patients using echocardiography, no differences in global left ventricular function and synchrony were noted; however, interventricular synchrony was superior with HBP [27]. Moreover, left ventricular synchrony assessed using single photon emission computed tomography hase analysis was similar in patients with HBP and those with LBBAP in whom a fascicular potential was visualized at implantation [28].

Most observational data suggested no difference in left ventricular ejection fraction (LVEF) or clinical outcomes between HBP and LBBAP [16, 29, 30]. An exception is the recent report by Tan et al. who reported a greater incidence of heart failure hospitalization and mortality in 119 patients with HBP compared with 163 patients with LBBP [19]. Vijayaraman et al. published the largest series comparing the two pacing modalities and included 163 and 196 patients with HBP and LBBAP, respectively [29]. No differences in heart failure hospitalization were noted, with a trend of higher mortality with HBP over a mean follow-up of approximately two years.

The only randomized comparison was reported in 21 patients with AV node ablation and successful implantation of both HBP and LBBP, who were randomized during six months to each pacing strategy [31]. No difference in LVEF was observed between the pacing periods; however, a greater improvement in the right ventricular function was noted during HBP.

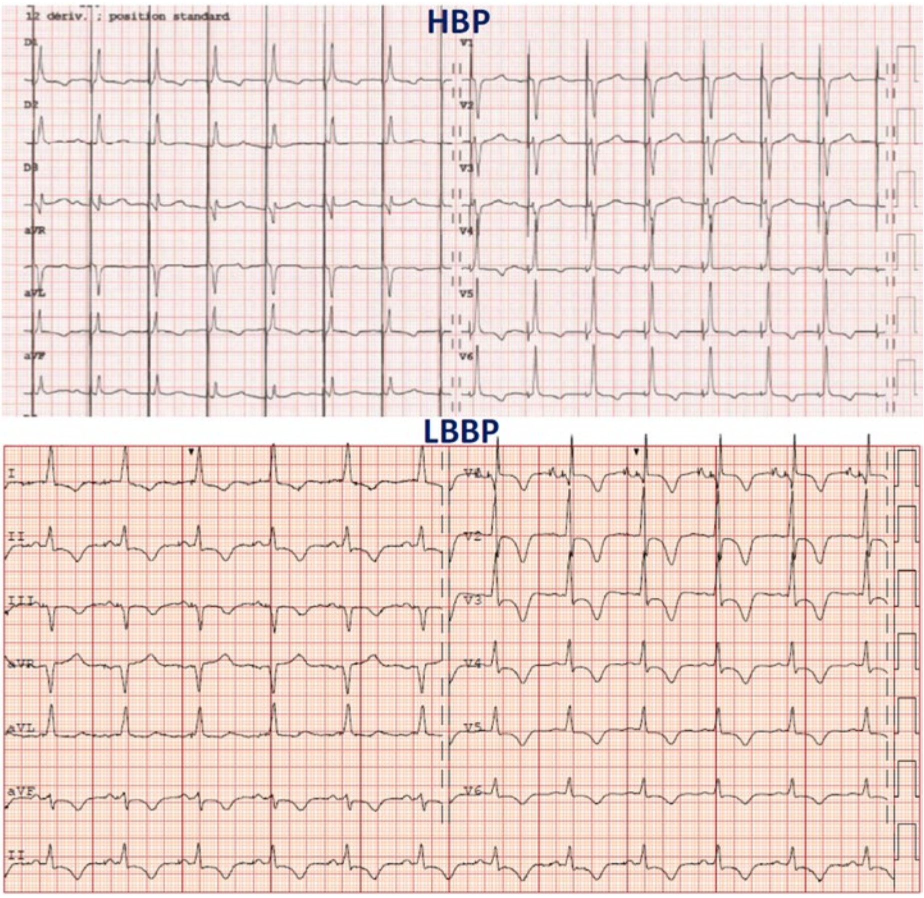

Figure 3: Two patients with complete atrioventricular block. Top: Nonselective His bundle pacing (HBP) in the unipolar pacing mode. Note the pseudo-delta wave resulting from myocardial capture in addition to His bundle capture. Bottom: Left bundle branch pacing (LBBP) in the bipolar pacing mode. Note the pseudo-right-bundle branch block appearance of the QRS complex resulting from the capture of the left septal myocardium and midseptal fascicles of the left bundle branch.

Device Programming and Follow-up

HBP programming can be complex, especially if the lead is connected to the atrial port in the presence of a ventricular backup lead (implanted for safety reasons to provide reliable sensing and/or pacing) [32]. LBBAP leads usually do not require ventricular backup leads and are most frequently connected to a ventricular port, making programming more straightforward [33].

To evaluate the presence of a conduction system capture, a 12-lead ECG is mandatory during follow-up.

Complications

The main issue with HBP is unsatisfactory electrical parameters. Several studies have reported a relatively frequent need for lead revision with HBP owing to lead dislodgement, increase in capture thresholds, and sensing issues. High capture thresholds may lead to premature battery depletion [34]. The increase in capture threshold with loss of His bundle capture has been described in 17% [35], 23% [19], and 53% [36] of patients; however, this early report did not use currently available tools and techniques. During the initial learning curve, lead revision is as high as 13% [37].

Owing to the HBP lead location and its implantation in fibrous tissues (with little surrounding ventricular myocardium), atrial and His potential oversensing (which can be potentially fatal in a pacemaker-dependent patient) and ventricular undersensing are HBP-related issues, which are not observed with LBBAP.

Current guidelines have recommended backup ventricular lead implantation for HBP in selected situations [38], including pacemaker dependency, infranodal AV block, pace-and-ablate strategy (where lead function may be compromised because of ablation site proximity) [39, 40], or sensing issues. Owing to the safe distance from the ablation site, the increase in the threshold in cases of AV node ablation is not an issue for LBBAP.

In a series of 323 patients implanted with lumenless leads, the loss of conduction system capture with LBBAP is 4.6% [41], and in another series including patients with stylet-driven leads, it was as high as 13.5% [19]. However, in these instances, myocardial capture is generally maintained; therefore, there is only little risk of asystole (contrary to HBP, where an increase in both His and myocardial capture thresholds are more frequently observed).

Table 1: Advantages and limitations of His bundle pacing (HBP) and left bundle area pacing (LBBAP)

HBP	LBBAP
Advantages	*Advantages*
Maximum electrical synchrony (narrow QRS). Endpoints well defined for successful His capture. Relatively good mid-term evidence for safety and efficacy. Avoids tricuspid regurgitation. Some evidence of medium and long-term lead extraction.	Low and reliable capture thresholds. Good sensing parameters. Large target area. Consistent backup myocardial capture (in addition to anodal capture by the ring electrode). Correction of more distal conduction disease. No requirement for backup pacing leads. AV nodal ablation without risk of compromising lead function.
Limitations	*Limitations*
Capture thresholds may be high. Sensing issues (atrial and His oversensing, ventricular undersensing). High rate of loss of capture and requirement for lead revision. Small target area. Limited to correction of proximal conduction block only. Risk if distal conduction block develops over follow-up. Risk of compromising lead function with AV node ablation. Backup ventricular leads may be indicated in specific situations. Complex programming in case of backup leads.	Less electrical synchrony compared to HBP, especially in patients with normal baseline QRS). Conduction tissue capture may be difficult to demonstrate and usually requires electrophysiology recording system for measurements. Complications specific to transseptal route (septal perforation, lesions to coronary vessels, septal hematoma etc.). Tricuspid regurgitation. May be challenging in patients with septal scar. Limited (but growing) evidence for mid-term safety and efficacy. Long-term extractability needs to be demonstrated.

AV: Atrioventricular.

Perioperative septal perforation, which may occur in up to 14% of patients, is one of the most frequent complications of LBBAP [42]. When properly recognized and the lead is repositioned, it usually does not have any consequences. Other complications include AV block or right bundle branch block (which may be permanent in some cases), lesions in the coronary vessels with acute coronary events [23, 43, 44], septal hematoma [45], and fistula formation [23].

Tricuspid regurgitation increases with LBBAP when the lead is implanted in a relatively basal position, presumably because of interaction with the leaflet and subvalvular apparatus [46, 47]. Conversely, the risk of lead-mediated tricuspid dysfunction in HBP is minor and may even improve regurgitation [48]. This finding could be due to the lead being positioned on the atrial aspect of the annulus or in the commissure between the septal and anterior leaflets with little interaction with valve function. HBP and LBBAP have been associated with mitral regurgitation improvement, probably because of ventricular remodeling in patients with heart failure [49, 50].

Damage to the helix at implantation requiring lead exchange may occur due to the entanglement with endocardial tissues and is more frequent with HBP than with LBBP [51]. Lead survival at five years has been described for HBP [34]. The Medtronic product performance report for the 3830 model used for HBP currently indicates a 90.6% lead survival rate at six years [52]. To date, no data has been reported on lead survival for this lead when it is used for LBBAP; however, bench-testing results are encouraging [53]. However, a case report on stylet-driven lead fracture six months following LBBAP implantation has been noted [54]. Therefore, this issue should be closely monitored, as unusual stress on the lead may occur (e.g., at the hinge point just proximal to the penetration of the septum), which may compromise lead integrity.

Furthermore, the feasibility of extracting LBBAP leads, which are bored deep into the septum, remains unknown. Data is currently limited to case reports, with a dwell time of approximately two years [55, 56]. The 3830 lead, being lumenless, does not permit the use of locking stylets. Cutting the lead connector makes the lead prone to stretching. If extraction sheaths are to be used, special preparation of the lead by peeling off the silicone connector sleeve and the use of lead extenders are necessary [57]. However, a previous study reported that HBP leads are relatively straightforward to extract, with a mean dwell time of 25 months [58], and extraction was successfully performed in a case report of a patient who had an HBP lead for 14 years [59].

Indications and Current Guidelines

HBP was first introduced in the 2019 European Society of Cardiology (ESC) supraventricular tachycardia guidelines as a class I (level of evidence C) indication for a "pace-and-ablate" strategy in case of tachycardiomyopathy [60]. The 2021 ESC pacing guidelines provided the same indication and HBP as an alternative to RVP in patients with LVEF >40%, a class IIb (level of evidence C) recommendation [38]. HBP was provided a class IIa (level of evidence C) indication as a bailout strategy in case of failed coronary sinus lead implantation, without any first-line indication for CRT. No recommendations were provided regarding LBBAP owing to the paucity of data when writing the guidelines. The 2023 Heart Rhythm Society guidelines on physiological pacing are slightly more liberal but generally provide the same weight for HBP as for LBBAP and do not provide any preference for one technique over the other [61].

Conclusion

HBP and LBBAP have advantages and limitations, which are listed in table 1. Overall, HBP may provide slightly more narrow QRS complexes than LBBAP; however, this instance does not seem to affect cardiac function or clinical outcomes. Conversely, LBBAP provides more favorable and reliable electrical parameters. In some instances, it is preferable to perform HBP, such as in patients with tricuspid valve abnormalities or in patients with a transmural septal scar in whom LBBAP is likely to fail. Conversely, in patients with infranodal block in whom there may be concerns for distal progression of the conduction disease or in case of pace-and-ablate strategy, LBBAP is the preferred technique to avoid compromising conduction system capture by the ablation. However, in most cases, either of the techniques may be employed, and it is a matter of operator experience and preference. Performing both techniques is significantly useful, as they may be interchangeably used as bailout strategies in case of difficult or suboptimal results with the initial technique, thereby improving the overall CSP procedural success rate. Evolution in the design of pacing leads and accessories are believed to improve the ease of implantation and success rates for HBP and LBBP, further increasing CSP adoption for the benefit of our patients.

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Conflict of Interest Statement

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MK has no potential conflict of interest to declare.

Author Contributions

M.K. drafted the manuscript, which was revised by H.B.

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You will find the full list of references online at https://cvm.swisshealthweb.ch/en/article/doi/cvm.2024.1379472814/.