

# Left bundle branch pacing is the best approach to physiological pacing

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The last decade has seen the resurgence of conduction system pacing (CSP) for patients with symptomatic bradycardia and heart failure. His-bundle pacing (HBP) is now an accepted alternative to more traditional ventricular pacing sites (right ventricular [RV] apex/outflow tract, coronary sinus).<sup>1</sup> Although HBP is theoretically the *ideal* physiological pacing site, it has some inherent limitations. The implant technique requires greater expertise in targeting a small zone and can be challenging in patients with dilated hearts, resulting in long procedural and fluoroscopic times. The reported success rate for HBP varies from 56% to 95%, depending on the degree of conduction system disease present and the experience of the center.<sup>2–4</sup>

Successful HBP lead implantation is fraught with troubleshooting issues during follow-up.<sup>5</sup> HBP leads typically have a low R-wave amplitude that may result in oversensing of atrial or His signals and undersensing of ventricular signals. High HBP capture thresholds at implant and/or during late follow-up may result in premature battery depletion and repeated generator replacements and the associated risks.<sup>6</sup> The unpredictable, delayed rise in HBP capture thresholds are a major concern, resulting in higher lead revision rates.<sup>4,7</sup> A subset of patients may also lose His capture during follow-up, resulting in RV septal pacing.

No robust data regarding the long-term performance of HBP leads are available. In the largest observational, 2-center study, 844 patients who received HBP leads had a mean pacing capture threshold of 1.6 V at implant and 2 V at median follow-up of 3 years.<sup>7</sup> HBP was free of any complications in 91% of patients. However, a careful appraisal of the data highlights the concerns noted in about 35%–40% of the patients. Pacing thresholds were  $\geq 2.5$  V at 1 ms in 28% of patients at median follow-up. Follow-up electrocardiography

showed septal pacing in 9% of patients. Lead revision was required in 7.6% of patients. Median time for battery replacement was 5.8 years.<sup>7</sup>

The quest for an optimal pacing site led to a novel CSP technique described by Huang et al<sup>8</sup> in 2017, where the pacing lead was implanted deep in the RV basal septum to capture the left bundle branch (LBB) area in a patient with heart failure and left bundle branch block (LBBB). Since its original description, few studies have demonstrated the feasibility of left bundle branch area pacing (LBBAP) (Table 1).<sup>9–19</sup> LBBAP is rapidly emerging as an alternative for failed HBP cases or as a primary strategy (in some centers) for CSP. Both anatomy (narrow target for His bundle [HB] vs wide target for left bundle branch area [LBBA]) and histology (His encased in fibrous, electrically nonconducting tissue vs LBB embedded in myocardium) favor LBBA over HB for physiological pacing.

## Step-by-step approach to LBBAP implant technique

LBBAP is performed using a SelectSecure 3830 pacing lead (Medtronic, Minneapolis, MN), delivered via either the fixed-curve C315-HIS sheath or the new SelectSite C304-HIS deflectable sheath (Medtronic). The 12-lead electrocardiographic recording and the intracardiac electrograms (EGMs) from the pacing lead are simultaneously displayed and continuously recorded on an electrophysiological recording system (Prucka CardioLab, GE Healthcare, Waukesha, WI). The steps in the implant procedure area as follows.

1. The distal His-bundle potential is located on the right anterior oblique fluoroscopic view using the delivery sheath and the 3830 lead, and the fluoroscopic position is saved for reference. If the His-bundle potential is difficult to locate, the tricuspid annulus (defined anatomically or electrically) or prosthetic valves (when present) can be used as a reference.
2. The sheath is turned clockwise and gently advanced 1.5–2 cm into the ventricle toward the RV basal septum (Figures 1A and 1B).

**KEYWORDS** Cardiomyopathy; Heart failure; His-bundle pacing; Left bundle branch area pacing; Physiological pacing; Right ventricular pacing; Ventricular dyssynchrony (Heart Rhythm 0<sup>2</sup> 2020;1:59–67)

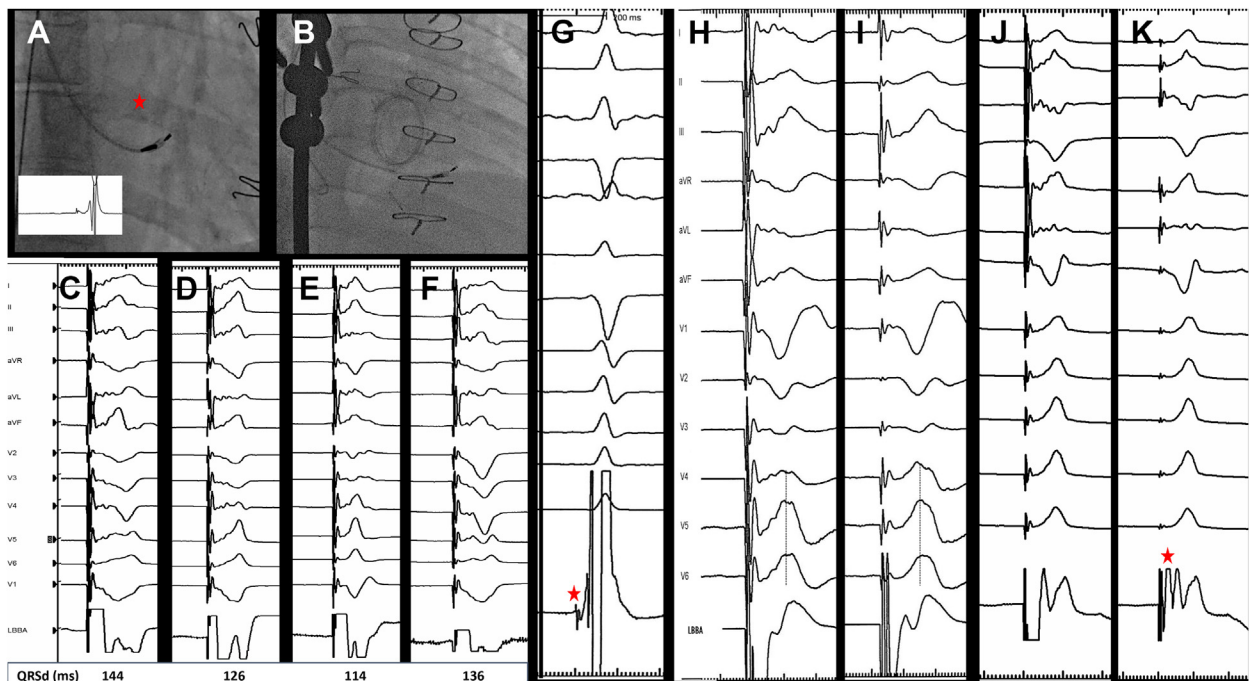
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**Table 1** Published studies on left bundle branch area pacing

Study (year)	Design	Sample size	Study population	Success rate	Mean paced		LBB potential	Follow-up (mo)	Lead complications	Outcomes
					QRSd (ms)	Mean LVAT (ms)				
Chen et al (2018)	Prospective LBBAP vs RVP	20	SND: 75% AV/infranodal block: 20%	NR	111 ± 10	69 ± 9	55%	3	A/C: None	Stable lead parameters
Zhang et al (2019)	Prospective LBBAP vs RVP	23	SND: 48% AVB: 38%	87%	112 ± 12	NR	NR	NR	A: None C: NR	Acute success rate and pacing characteristics
Hou et al (2019)	Prospective	56	SND: 29% AVB: 37% AF with SVR: 34%	NR	118 ± 11	76 ± 14	67%	4.5	A: 1 lead dislodgment intraoperative C: None	Stable lead parameters LBBAP patients with potential had LV mechanical synchrony similar to that of HBP based on phase analysis of gated SPECT MPI
Li et al (2019)	Retrospective	33	AVB: 100%	91%	113 ± 11	82 ± 15	26.7%	3	A: 1 LV septal perforation C: None	Stable LVEF Stable lead parameters
Li et al (2019)	Prospective	87	SND: 68% AVB: 32%	80%	113 ± 10	79.7 ± 8.5	66%	3	A/C: None	Stable LVEF Stable lead parameters
Vijayaraman et al (2019)	Prospective	100	SND: 23% AVB: 54% AVN ablation: 7% CRT: 11% HBP failure: 7%	93%	136 ± 17	75 ± 16	63%	3	A: 3 lead dislodgments within 24 h requiring revision; 3 LV septal perforations C: None	Stable lead parameters
Zhang et al (2019)	Prospective	11	HF with reduced EF and LBBB: 100%	NR	129 ± 16	80.9 ± 9.95	0%	6.7	A/C: None	Stable lead parameters Improvement in LVEF by >5% from baseline in all, >20% from baseline in 7 patients Improvement in LV synchrony by pulsed-wave Doppler and tissue synchronization imaging

Hasumi et al (2019)	Retrospective	21	Advanced AVB: 100% Failed HBP	81%	116 ± 8.3	NR	NR	6	A/C: None	Stable lead parameters
Cai et al (2020)	Prospective Observational LBBAP vs RVP	40	SND: 100%	90%	101 ± 8.79	LBBAP with normal axis: 59 ± 6; left-axis deviation: 64 ± 4.5	80%	Echocardiogram on day 3	NR	LBBAP preserved mechanical synchrony similar to native conduction LBBAP leads to favorable hemodynamic effects RVP resulted in electrical and mechanical dyssynchrony and worse hemodynamic effects
Jiang et al (2020)	Retrospective	73	BBB with QRSd >130 ms Atypical BBB:13.6% 5 LBBB and 5 RBBB Typical BBB: 86.4% 30 LBBB and 33 RBBB	30% 82.5%	133 ± 14 118 ± 14	103 ± 23 85 ± 15	10% 28.6%	NR	A: 4 LV septal perforations C: None	Typical BBB morphology (Strauss criteria) predicts successful QRS correction with LBBAP
Wang et al (2020)	Prospective Randomized LBBAP vs RVP	66	SND: 32% AVB: 54% AF with SVR: 14%	94%	121 ± 9.8	67.8 ± 6.8	75%	6	A: 1 lead perforation at 1 month requiring revision C: 2 lead dislodgments (1 at 2 mo, 1 at 4 mo)	Stable lead parameters LBBAP resulted in narrower QRSd, shorter QT and QTc interval, lower QTD and QTcD shorter T <sub>peak-end</sub> interval compared with RVP, suggesting better depolarization-repolarization reserve
Total		530							6 lead dislodgments 9 septal perforations	

A = acute; AF with SVR = atrial fibrillation with slow ventricular rate; AV = atrioventricular; AVN = atrioventricular node; AVB = atrioventricular block; BBB = bundle branch block; C = chronic; CRT = cardiac resynchronization therapy; EF = ejection fraction; HBP = His-bundle pacing; HF = heart failure; LBB = left bundle branch; LBBAP = left bundle branch area pacing; LBBB = left bundle branch block; LV = left ventricle; LVAT = left ventricular activation time; LVEF = left ventricular ejection fraction; NR = not reported; QTc = corrected QT interval; QTD = QT dispersion; QTcD = corrected QT dispersion; RBBB = right bundle branch block; RVP = right ventricular pacing; SND = sinus node dysfunction; SPECT MPI = single photon emission computed tomography myocardial perfusion imaging.



**Figure 1** **A:** Fluoroscopic right anterior oblique view. *Asterisk* indicates the distal His-bundle position. *Inset* shows distal His-bundle electrogram (EGM). The sheath and 3830 lead are advanced about 2 cm distal to the distal His-bundle EGM. **B:** The sheath and 3830 lead are advanced about 2 cm distal using the bioprosthetic aortic valve as a reference. **C:** Ideal site for lead fixation showing left bundle branch (LBB) QRS morphology with inferior lead and aVR/aVL discordance. **D:** After 4 turns, note QRSd narrowing and V<sub>1</sub> morphology. **E:** After 2 more turns, unipolar tip pacing revealed stim-QRS latency of 20 ms, right bundle branch block morphology with rsR' in lead V<sub>1</sub>, and QRSd of 114 ms suggesting capture of left bundle branch area (LBBA). **F:** Unipolar ring pacing reveals right ventricular basal septal capture with LBB morphology and QRSd of 136 ms. **G:** *Asterisk* indicates LBB potential. LBB potential to QRS duration was 20 ms. **H, I:** Stimulus to peak of R wave in lead V<sub>5</sub> (left ventricular activation time) at 5 and 1 V, respectively, was short and constant at 65 ms. **J, K:** Threshold testing during unipolar tip pacing showing transition from nonselective left bundle branch block area pacing (LBBAP) to selective LBBAP at 0.6 V at 0.4 ms. *Asterisk* indicates the discrete EGM with selective LBBA capture.

- Unipolar pacing is performed to assess for an ideal site for lead fixation: a paced morphology of QS complex with a notch in the nadir in lead V<sub>1</sub> and/or presence of inferior lead and aVR/aVL discordance (R wave in lead II taller than lead III, negative aVR and positive aVL) (Figure 1C).
- If the above criteria are met, the lead is fixed to the RV septum by 1–2 rotations. Unipolar pacing is performed to confirm the ideal paced QRS morphology and importantly to rule out inadvertent repositioning of the lead in the RV outflow tract (Figure 1D). Baseline pacing impedance is documented.
- The sheath is gently advanced to abut the septum and rotated (typically counterclockwise) to make the sheath tip/lead perpendicular to the septum (approximately 10° clock in the right anterior oblique view and 2–30° clock in the left anterior oblique view).
- With an assistant holding the sheath in this position (can also be done by a single operator), the pacing lead is rapidly rotated clockwise 4–5 turns, preferably using both hands, under fluoroscopy (Supplemental Video 1).
- Unipolar tip pacing is performed to assess the paced QRS morphology and pacing impedance. Further clockwise rotations are given, 1 or 2 at a time, until the paced QRS morphology resembles right bundle branch (RBB) conduction delay or right bundle branch block (RBBB) pattern in lead V<sub>1</sub> (qR or rsR') (Figure 1E). As the lead

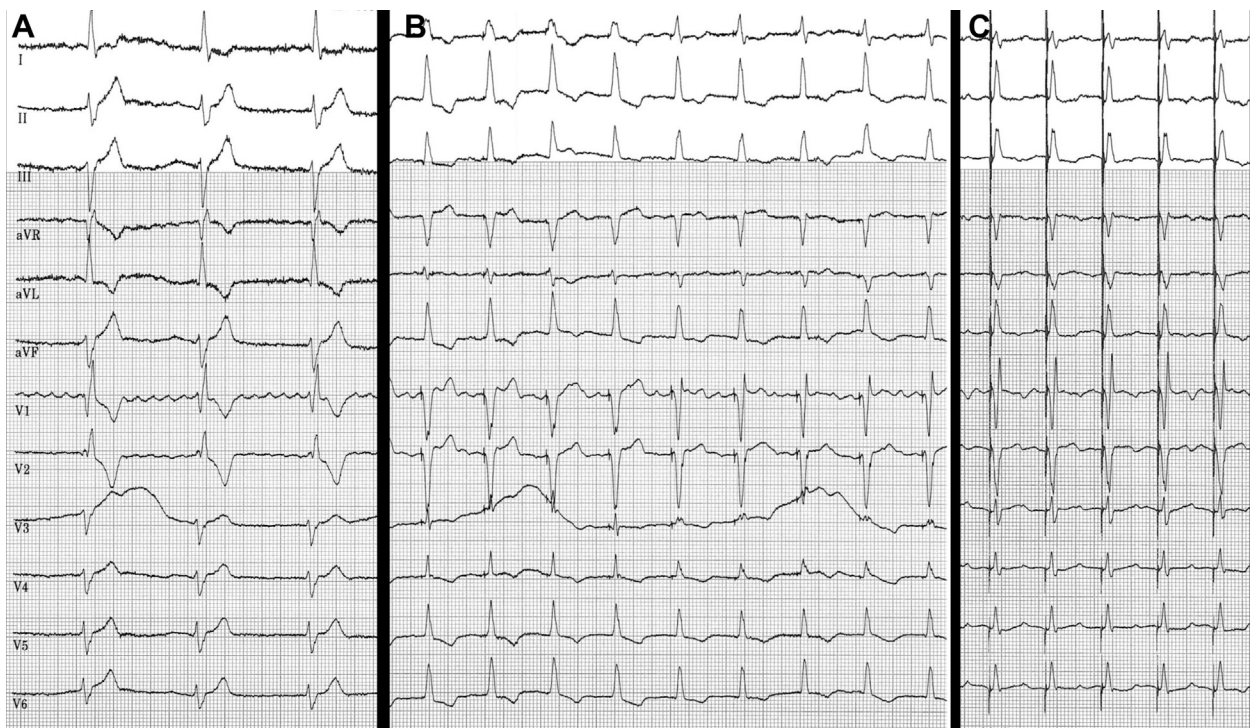
penetrates into the septum, initially the impedance gradually rises, and as the lead tip reaches the LBBA the impedance gradually falls by about 100 Ω. Unipolar ring pacing capture confirms the presence of the ring electrode in the septum (Figure 1F). LBB potential is recorded, when present (Figure 1G). The sensing, threshold, and impedances are recorded. LBBAP is confirmed by previously published criteria.<sup>20</sup>

- A septogram (1–2 mL of contrast injected through the sheath) can be performed in the left anterior oblique fluoroscopic view, to delineate the RV septal wall and confirm the lead depth in the interventricular septum (Supplemental Video 2). The distance between the screw tip and the ring electrode is 10.8 mm, which provides an approximate measure of lead depth in septum. Alternatively, unipolar ring pacing capture provides a rough estimate of lead depth in the septum. Lead depth can also be assessed on echocardiogram (Supplemental Video 3).

### Approach to a challenging implant

If the LBBAP criteria are not met despite adequate lead depth in the septum or the lead will not penetrate deep into septum (unwinds or backspins) possibly due to fibrosis (Supplemental Video 4), the lead should be repositioned to a distal location on the septum. Typically, 8–12 turns are





**Figure 2** A 64-year-old woman with rheumatic valvular heart disease, mechanical aortic and mitral valve replacement 25 years ago, and severe aortic stenosis who received a bioprosthetic aortic valve complicated by complete heart block. **A:** Electrocardiogram (ECG) showing atrial fibrillation with complete heart block, right bundle branch block, and left anterior fascicular block (LAFB) escape with QRSd of 142 ms. **B:** ECG rhythm strip after left bundle branch area (LBBA) pacing lead implant during VVI bipolar pacing. Note the change in QRS morphology in lead V<sub>1</sub> from QS to Qr at 3 V at 0.4 ms, with further narrowing of QRSd. This is due to loss of ring/anodal capture. **C:** Follow-up ECG of presenting rhythm 1 month later in the device clinic at 2 V at 0.4 ms. Threshold was 0.5 V at 0.4 ms. Pacing shows right bundle branch (RBB) conduction delay and normal axis with relatively narrow QRSd of 124 ms. LBBA pacing resulted in partial correction of RBB and complete correction of LAFB.

needed to reach left ventricular (LV) subendocardium to capture the LBBA.

The If C315-HIS sheath does not provide enough reach to get to the ideal location, the deflectable C304-HIS sheath can be used for better reach and maneuverability. Figures 2–4 show successful LBBAP in various case scenarios.

### Determining LBBA capture

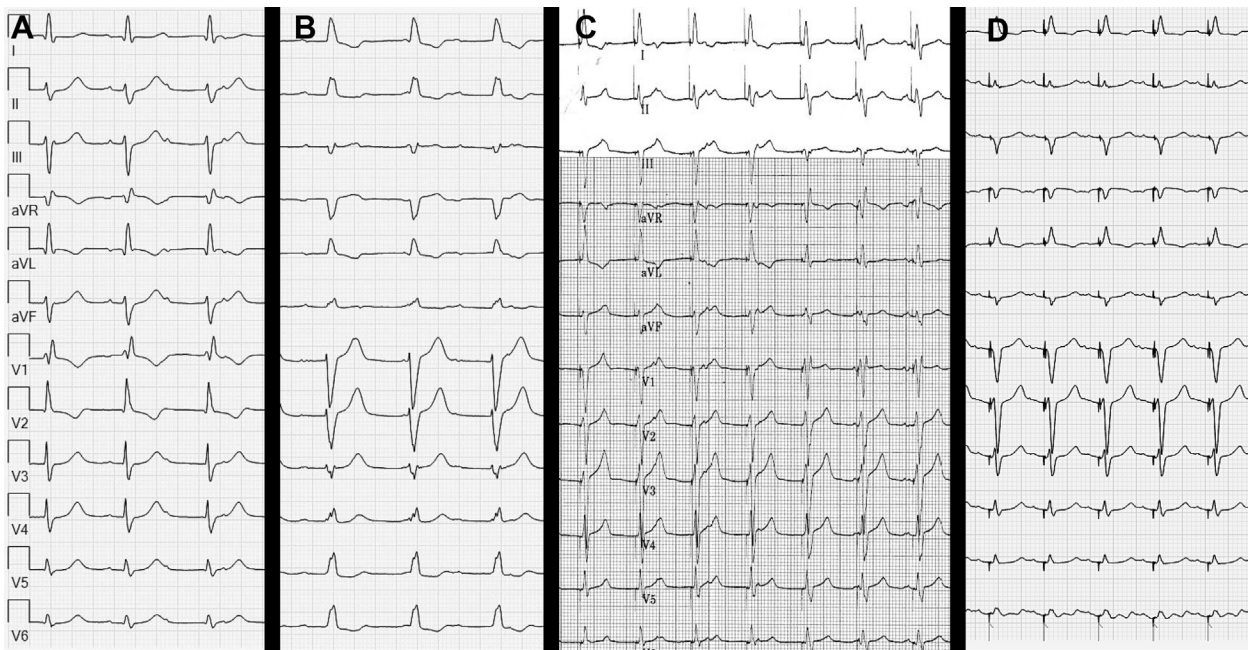
Mafi-Rad et al<sup>21</sup> demonstrated the feasibility of LV septal pacing using a custom-designed lead implanted in mid-distal septum. LV septal pacing resulted in a narrower QRS ( $144 \pm 20$  ms) and provided acute hemodynamic benefits over RV pacing. Both LV septal pacing and LBBAP can result in a relatively narrow QRS with RBB morphology. When CSP is intended, it is imperative to demonstrate LBBA capture. However, whether clinical outcomes differ between LV septal pacing and LBBAP remains to be determined.

The criteria for determining LBBA capture are being defined and need to be validated in future studies. Huang et al<sup>20</sup> proposed criteria to demonstrate LBBA capture. Successful LBBAP is considered when  $\geq 3$  of the following criteria are met:

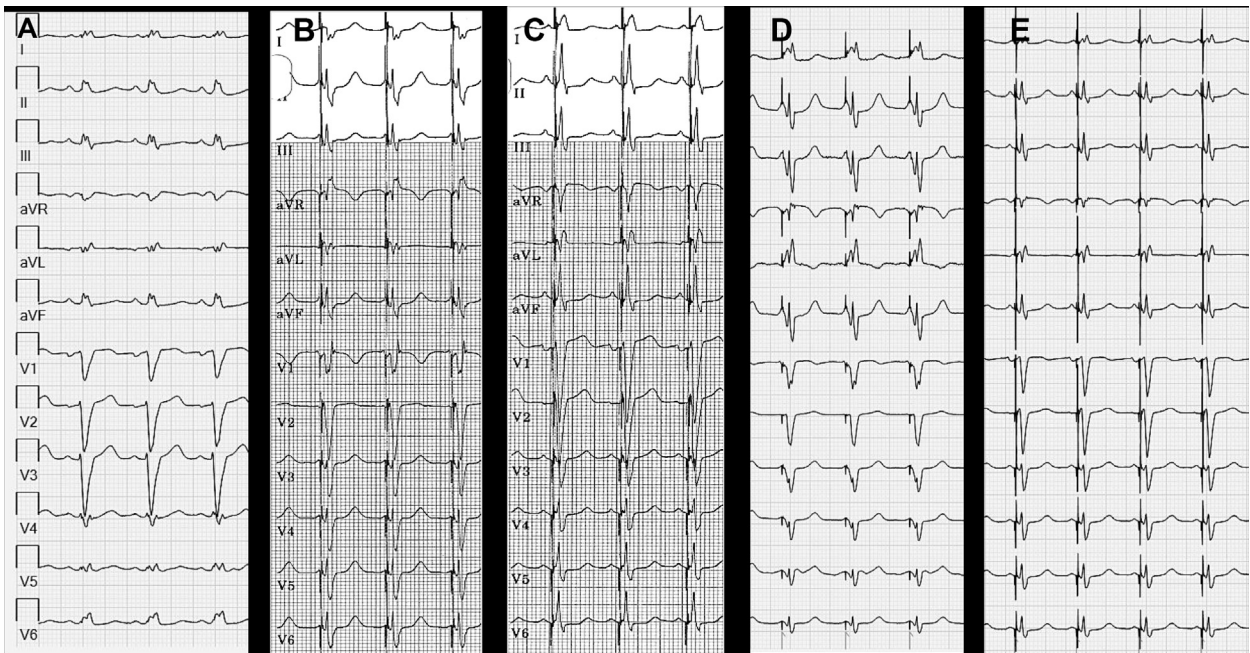
1. Paced morphology of RBBB pattern
2. Presence of LBB potential

3. Left ventricular activation time measured from stimulus to peak of R wave in lead V<sub>5</sub>/V<sub>6</sub>
  - Short and constant at high- (5 V) and low- (1 V) output pacing (Figures 1H and 1I)
4. Determination of selective (S) and nonselective (NS) LBB pacing (Figures 1J and 1K)
  - S-LBB: Stim-QRS latency and discrete local EGM separate from stimulus artifact seen
  - NS-LBB: No stim-QRS latency; no discrete local EGM separate from stimulus artifact
5. Evidence for direct LBB capture

Unlike HBP, LBBAP almost always results in simultaneous capture of the LBB and the surrounding myocardium due to its anatomic location in the muscular septum. Recently Jastrzębski et al<sup>22</sup> elegantly described programmed extrastimulus to differentiate LBB capture vs LV septal myocardial capture based on their differential effective refractory periods. Premature beats were delivered during sinus rhythm or after an 8-beat drive train at 600 ms with a 450-ms coupling interval, which was further stepwise decreased by 10-ms intervals. Response to premature beats was categorized as *myocardial* when the paced QRS morphology changed to myocardial-only capture (broader QRS, with slur/notch/plateau and/or with change in amplitude/polarity in several leads) or *selective LBB* when



**Figure 3** A 21-year-old woman with congenital aortic and mitral valve stenosis underwent mechanical aortic and mitral valve replacement complicated by complete heart block. **A, B:** Electrocardiograms (ECGs) showing complete heart block with alternating right bundle branch block/left anterior fascicular block and left bundle branch block escape rhythm. **C:** ECG rhythm strip after left bundle branch area (LBBA) pacing lead implant during VVI bipolar pacing. Note the change in QRS morphology in lead V<sub>1</sub> from QS to rsr' at 1.5 V at 0.4 ms. This is due to loss of ring/anodal capture. **D:** Follow-up ECG of presenting rhythm 1 month later in the device clinic at 2 V at 0.4 ms. This was the final pacing configuration, with QRSd of 110 ms and QS in V<sub>1</sub> suggesting anodal and LBBA capture. Threshold was 0.7 V at 0.4 ms. Echocardiogram 9 months later showed normal left ventricular ejection fraction despite 100% ventricular pacing (not shown).



**Figure 4** A 65-year-old woman with ischemic cardiomyopathy, ejection fraction (EF) 20% despite guideline-directed medical therapy, New York Heart Association (NYHA) functional class III, chronic left bundle branch block (LBBB) on home intravenous milrinone therapy referred for cardiac resynchronization therapy. Despite several attempts, the coronary sinus lead implant failed. A bailout left bundle branch area pacing lead was implanted. **A:** ECG showing sinus rhythm and LBBB with QRSd 156 ms. **B:** Pacing with AV delay set at 40 ms resulted in Left bundle branch area (LBBA) capture with right bundle branch block (rsR') in lead V<sub>1</sub> with QRSd of 128 ms. **C:** Pacing with AV delay set at 80 ms resulted in normalization of QRSd to 120 ms. This is due to fusion between anterograde right bundle branch conduction and LBBA pacing. **D:** Follow-up ECG in the device clinic in 1 month during threshold testing showed QS in lead V<sub>1</sub> during bipolar pacing with anodal capture threshold of 2.2 V at 0.4 ms. **E:** Final pacing configuration with AV delay set at 80 ms and output programmed at 2 V at 0.4 ms showing normalization of QRS complexes with QRSd of 120 ms. Threshold was 0.8 V at 0.4 ms. Of note, milrinone was discontinued the day after device implant. Follow-up echocardiogram 2 months later showed ejection fraction of 30%–35% (not shown). The patient required no heart failure hospitalizations and reported New York Heart Association functional class II symptoms 5 months after device implant.

**Table 2** Differences between HBP and LBBAP

	HBP	LBBAP
Anatomy	Narrow target zone (20 mm length, 4-mm diameter)	Wider target zone
Histology	Surrounding electrically inert fibrous milieu	Surrounding muscular tissue
Physiology	Preserves or restores RV and LV synchrony	Preserves or restores LV synchrony
Implantation	Technically challenging High precision Long learning curve	Relatively easier Less precision Short learning curve
Success rates in AV nodal and infranodal disease	Lower due to high thresholds or inability to correct the underlying conduction system disease	Higher as pacing beyond the site of block
Pacing morphologies	Selective His Nonselective His Myocardial capture	Selective LBB Nonselective LBB RV septum + LBB (anodal capture) Myocardial capture
Sensing R waves	Low amplitude <ul style="list-style-type: none"> <li>• Risk of oversensing atrial or His signals</li> <li>• Risk of undersensing ventricular signals</li> </ul>	High amplitude No sensing issues
Thresholds (acute)	Relatively higher as stimulating ventricles through a fibrous sheath	Lower
Thresholds (chronic)	Can be unstable, unpredictable, with a delayed rise; thresholds $\geq 2.5$ V @ 1 ms seen in 25%–30% of patients Possible hypothesis: <ul style="list-style-type: none"> <li>• Anatomic characteristics</li> <li>• Local fibrosis leading to exit block</li> <li>• Micro-dislodgment</li> <li>• Progression of disease</li> </ul>	Stable
RV backup lead	May be necessary in dependent patients	Not necessary
Lead complications <ul style="list-style-type: none"> <li>• Septal perforation</li> <li>• Dislodgments</li> <li>• Loss of conduction system capture</li> <li>• Lead revision rate</li> </ul>	<ul style="list-style-type: none"> <li>• Not reported</li> <li>• Possible</li> <li>• Up to 10%</li> <li>• High (8%–10%)</li> </ul>	<ul style="list-style-type: none"> <li>• Possible</li> <li>• Possible</li> <li>• To be determined</li> <li>• Low (1%)</li> </ul>
Device programming	Complex <ul style="list-style-type: none"> <li>• Selective HBP: shorten AV delays</li> <li>• Automatic capture thresholds turned off</li> <li>• Ventricular safety pacing turned off</li> <li>• High thresholds: unipolar or extended bipolar</li> </ul>	Simple <ul style="list-style-type: none"> <li>• AV delays adjusted in patients with LBBB to allow fusion</li> <li>• Autocapture turned on</li> <li>• Ventricular safety pacing turned on</li> </ul>
Battery longevity	Shorter Frequent generator replacements, associated risks	Longer
AV nodal ablation	Challenging Risk of damaging His lead	Relatively easy No risk of damaging LBBAP lead

AV = atrioventricular; HBP = His-bundle pacing; LBB = left bundle branch; LBBAP = left bundle branch area pacing; LBBB = left bundle branch block; LV = left ventricle; RV = right ventricle.

the paced QRS morphology changed to a typical RBB morphology preceded by a latency. Either myocardial or selective LBB was considered diagnostic of LBBA capture and was noted in 80% of the patients with LBBAP.<sup>22</sup>

### Does LBBAP preserve electrical and mechanical synchrony?

HBP is the most physiological mode of pacing that preserves or restores electrical and mechanical synchrony by simultaneous

activation of both ventricles.<sup>23</sup> In contrast, LBBAP by direct capture of the LBB preserves or restores physiological activation of the LV. Electrocardiographically, one would expect complete RBBB morphology, but often incomplete RBBB/RBB conduction delay pattern is noted with a relatively narrow QRS duration < 130 ms. The mechanism of incomplete RBBB during LBBAP is intriguing, and possible hypotheses include transverse connections between LBB and RBB,<sup>24,25</sup> retrograde activation of His and RBB during LBBAP, and virtual electrode effect.<sup>26</sup> Whether the delayed RV activation from LBBAP



could result in clinically significant interventricular dyssynchrony and pacing-induced cardiomyopathy is unknown. Limited studies have shown LV mechanical synchrony with LBBAP similar to that of HBP based on phase analysis of gated single photon emission computed tomography myocardial perfusion imaging,<sup>11</sup> to that of native conduction based on echocardiographic imaging,<sup>17</sup> and improved LV mechanical synchrony in patients with LBBB and heart failure based on echocardiographic imaging.<sup>8,15</sup>

### Acute clinical and safety outcomes with LBBAP

The initial results of small prospective observational studies on LBBAP are encouraging (Table 1). The overall success rate varied from 80%–94%. High success rates were achieved in patients with advanced conduction system disease. Lead parameters specifically capture thresholds remained stable during short-term follow-up. Furthermore, LBBAP holds tremendous promise in achieving cardiac resynchronization therapy in patients with heart failure and LBBB.<sup>8,15</sup> In a study of 11 patients with heart failure and LBBB, LBBAP resulted in LBB correction with significant narrowing of QRS from a mean of  $180 \pm 16$  ms to  $129 \pm 16$  ms.<sup>15</sup> Notably, the lead parameters remained stable, and there was significant improvement in left ventricular ejection fraction and dyssynchrony on echocardiographic imaging at mean follow-up of 6.7 months.<sup>15</sup>

LBBAP is an emerging pacing technique, and only the short-term safety profile is currently known. Of the 530 published cases (Table 1), 6 (1%) lead dislodgments (1 intraoperative, 3 within 24 hours, 1 at 2 months, and 1 at 4 months) and 9 (1.7%) septal perforations (8 intraoperative and 1 at 1 month) have been reported.<sup>11,12,14,18,19</sup> No major complications associated with perforation, including transient ischemic attack/stroke and pericardial effusion have been described. Lead-related complications, such as infection, sensing issues, and delayed threshold rise, have not been reported. Other potential complications, such as intramural hematoma, coronary artery injury, tricuspid regurgitation, risk of septal contractile stress fracture of the lead, and risk of lead extraction, need to be investigated in future clinical studies.

### Is LBBAP the “holy grail” of physiological pacing?

Based on the early clinical experience, LBBAP seems to be the best approach to physiological pacing and circumvents many of the limitations noted with HBP (Table 2). The large anatomic target site, technically less challenging procedure, easier lead fixation, shorter procedural and fluoroscopic times,<sup>13</sup> higher success rates, ability to preserve or improve LV synchrony,<sup>11,15,17</sup> and, most importantly, stable lead parameters with LBBAP argue strongly for LBBAP to be the holy grail of physiological pacing.

The rate of LBBAP technique adoption in clinical practice is fascinating. In China, 80% of 5000 CSP cases performed in 2018 were LBBAP.<sup>26</sup> In a recently published Polish experience, 40% of patients referred to an experienced center for CSP in 1 year received LBBAP leads after they failed to obtain an adequate result with HBP.<sup>22</sup> Our experience at Virginia Commonwealth University (VCU) also reflects a paradigm shift regarding the site of CSP. Approximately 300 HBP leads were implanted at VCU over a 5-year period (2014–2019). This is in striking contrast to 150 LBBAP leads implanted over a 1-year period (2019–2020). Similar to the published data, our experience with LBBAP has been incredibly positive, with high success rates, stable thresholds, and no major complications to date.

### Future directions

LBBAP is currently performed using the 3830 lead and C315-HIS or C304-HIS sheath, none of which were designed for LBBAP. Further refinements in technique and tools are needed for improvement of overall success rates. The criteria for LBB capture need to be further refined and validated. The long-term safety profile, lead integrity, and risk of extraction of deep septal LBBAP leads need to be determined. The role of LBBAP in patients requiring cardiac resynchronization therapy needs to be investigated in prospective randomized clinical trials.

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### Appendix

#### Supplementary data

Supplementary data associated with this article can be found in the online version at <https://doi.org/10.1016/j.hroo.2020.03.002>.

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