Atrioventricular block at the distal His bundle: Electrophysiological insights from left bundle branch pacing

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Introduction

Right ventricular (RV) pacing has been the mainstay of bradycardia therapy for several decades. However, the recognition of deleterious effects of RV pacing has led to the search for more physiologic forms of pacing. Permanent His bundle pacing (HBP) has recently been shown to be feasible and effective in potentially reducing heart failure hospitalizations and mortality.[1,2] Permanent HBP is successful in about three fourths of patients with infranodal atrioventricular (AV) block, establishing the site of block to be intra-Hisian.[3] In about 25% of patients with infranodal AV block, the site of block is presumed to be either at an inaccessible part of the distal His bundle or at an infra-Hisian (peripheral branches) level. Recently Huang and colleagues[4] showed the feasibility of pacing the left bundle branch (LBB) region in a patient with LBB block (LBBB). In this report we present electrophysiological insights from 2 cases of infranodal AV block in which LBB pacing was successfully performed.

KEY TEACHING POINTS

- Infranodal atrioventricular block is often due to conduction disease at the level of the main His bundle.
- Permanent His bundle pacing may require high outputs to correct the conduction delay in many patients with distal His bundle disease.
- Left bundle branch pacing by means of deep septal lead implantation may overcome atrioventricular blocks and bundle branch blocks not amenable to His bundle pacing.
- Unipolar pacing from the lead tip and ring and bipolar pacing demonstrated the electrophysiological characteristics of pacing the left bundle branch region.

Case report

Case 1

A 75-year-old woman presented with symptoms of intermittent episodes of near syncope and syncope. Electrocardiogram on presentation revealed underlying right bundle branch block (RBBB) and left anterior hemiblock with QRS duration of 155 ms and intermittent episodes of type II second-degree AV block. Permanent pacemaker implantation with HBP was attempted. During mapping with the pacing lead (SelectSecure, Medtronic, Minneapolis, MN), His-ventricle (HV) interval was noted to be 95 ms. Despite extensive mapping, a distal pacing site with acceptable His capture threshold (<2.5 V) and bundle branch block correction could not be achieved (Figure 1A). Subsequently using the same delivery catheter (C315His, Medtronic) the pacing lead was successfully implanted about 1 cm distally, deep in the interventricular septum at the LBB region. A sharp LBB potential was recorded at the location with LBB-V interval of 25 ms. R-wave amplitude was 15 mV. Unipolar pacing from this site at decreasing outputs demonstrated narrow RBBB morphology during nonselective LBB pacing at outputs up to 0.7 V @ 0.5 ms and selective LBB capture at 0.5 V @ 0.5 ms (Figure 1B). Unipolar pacing from the tip and ring electrode was performed to demonstrate the engagement of the conduction system. During unipolar pacing from the tip electrode the retrograde conduction to the right atrium was 190 ms, compared to 240 ms during unipolar pacing from the ring electrode (Figure 1C). Schematic representation of

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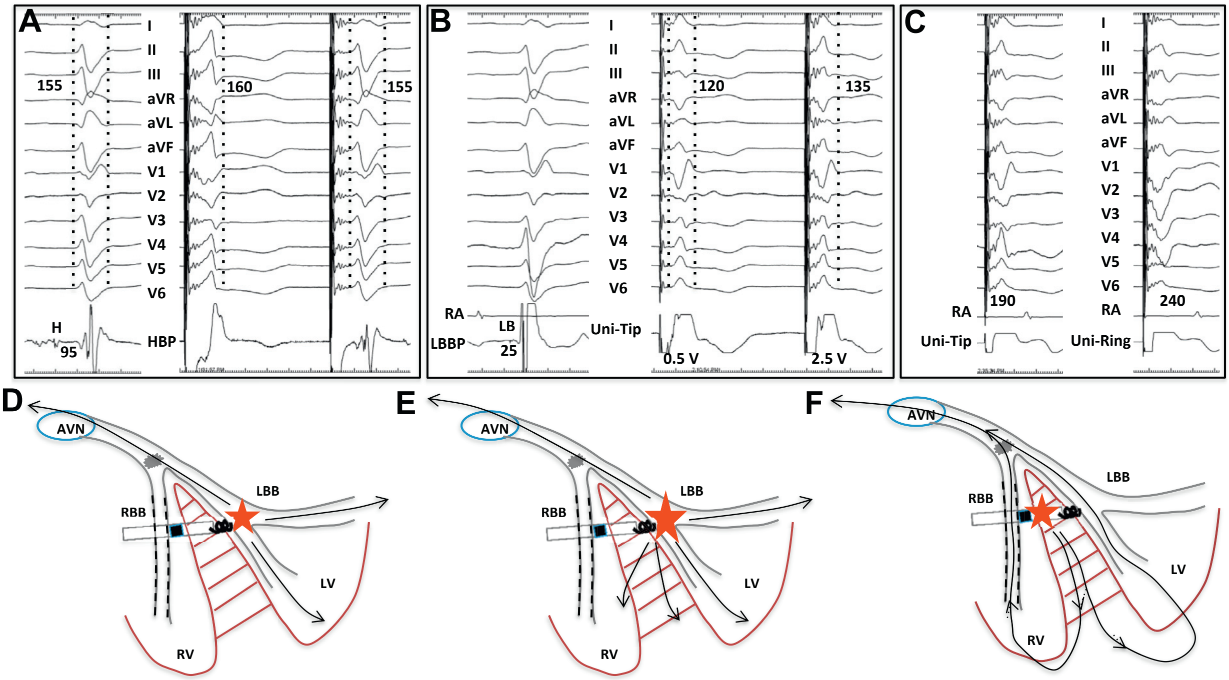

Figure 1 Left bundle branch pacing (LBBP) in a patient with bifascicular block. Twelve-lead electrocardiogram and electrograms from His bundle pacing (HBP), right atrium (RA), and LBBP leads are shown at a sweep speed of 50 mm/s. **A:** Prolonged His (H)-ventricle interval of 95 ms in the setting of right bundle branch (RBB) block and left anterior hemiblock. Nonselective-to-selective HBP without correction of underlying bifascicular block. **B:** Unipolar electrograms obtained from the lead tip placed deep in the septum shows sharp left bundle branch (LBB) potential with LB-V interval of 25 ms. Output-dependent selective and nonselective LBBP are shown. **C:** The stimulus-to-RA interval prolongs from 190 ms during unipolar pacing from the lead tip (LBB capture) to 240 ms during unipolar pacing from the ring electrode (right ventricular capture). **D–F:** Schematic representation of conduction patterns during selective and nonselective LBBP from the lead tip and pacing from right ventricular septum (ring electrode). AVN = atrioventricular node; LV = left ventricle; RV = right ventricle.

nonselective and selective LBB pacing from the tip electrode and RV septal pacing from the ring electrode are shown in Figure 1D–F. Fluoroscopic views of the LBB pacing lead are shown in Supplemental Figure 1.

Case 2

A 74-year-old man presented with symptoms of fatigue and weakness. Electrocardiogram revealed underlying LBBB with QRS duration of 160 ms and 2:1 AV block. Mapping

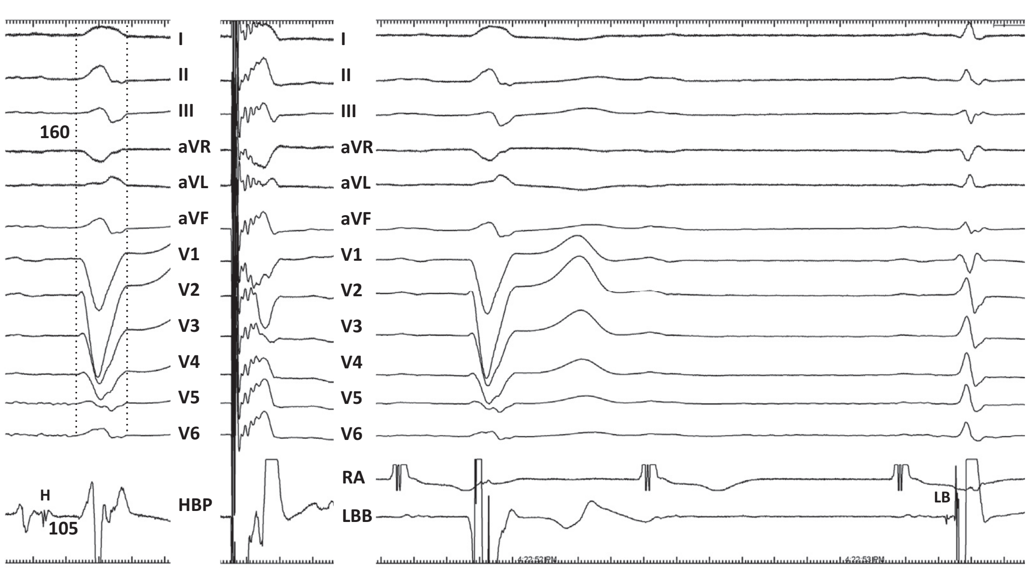

Figure 2 His bundle pacing (HBP) vs left bundle branch (LBB) pacing. Twelve-lead electrocardiogram and electrograms from HBP and LBB pacing lead are shown at a sweep speed of 100 mm/s. LBB block and prolonged His (H)-ventricle interval of 105 ms and high-grade atrioventricular block. Nonselective HBP with correction of LBB block, but only at high output. Electrograms from the LBB pacing lead demonstrate sharp potential 20 ms pre-QRS, only during narrow QRS following a blocked beat but not during LBB block. RA = right atrium.

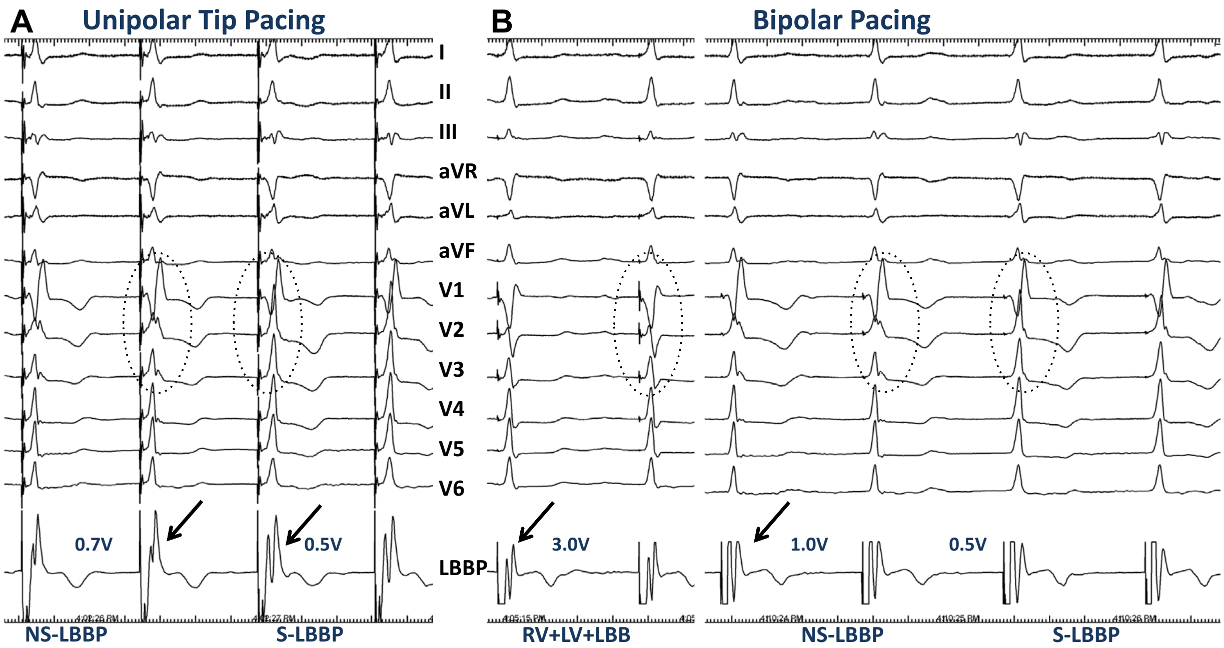

Figure 3 Unipolar vs bipolar pacing from left bundle branch pacing (LBBP) lead. **A:** Output dependent nonselective (NS) and selective (S) LBBP during threshold testing with significant QRS morphology changes in V_1–V_3. **B:** During bipolar pacing at high output, in addition to NS LBBP pacing there is fusion from right ventricular (RV) septal (anodal) capture as the ring electrode is abutting the RV septum with partial correction of the right bundle branch block pattern. Note the corresponding changes in the electrograms of the LBBP lead (*arrow*). LBB = left bundle branch; LV = left ventricle.

the His bundle revealed long HV interval of 105 ms and 2:1 HV block. Only at high output pacing, HBP resulted in LBBB correction and this position could not be accepted (Figure 2). Deep septal pacing was attempted and the lead was placed about 10 mm distal to the His bundle and approximately 10 mm deep in the septum. R-wave amplitude at this site was 12 mV. While no potential was observed during LBBB, intermittent RBBB/narrow complex was observed with discrete LBB potentials 20 ms pre-QRS (Figure 2). This suggests that the site of block was at the level of the distal His bundle. Nonselective-to-selective LBB capture was observed during unipolar pacing from the lead tip at decreasing outputs near threshold values (Figure 3A). During bipolar pacing at 3.0 V @ 0.5 ms and above, there was evidence for anodal RV septal capture in addition to nonselective LBBP. Below 3.0 V, nonselective LBBP was observed similar to unipolar pacing at up to 1.0 V and below which there was selective LBB capture with QRS duration of 120 ms (Figure 3B). Fluoroscopic views of the HBP lead and LBB pacing lead location are shown in Supplemental Figure 2.

Discussion

Permanent HBP is an effective form of physiologic pacing with high success rates in patients with intact His-Purkinje conduction. However, in patients with infranodal AV block and underlying bundle branch blocks, success rates are somewhat limited depending on the site of block in the His bundle and the anatomic course of the distal His bundle. In both these cases, the site of block was intra-Hisian but likely in the distal segment of the His bundle, as demonstrated by BBB correction at high outputs. However, owing to deeper course of the distal His bundle, optimal permanent HBP could not be achieved. The recording of LBB potentials with short LBB-V intervals in the setting of long HV intervals confirms the site of conduction disease to be proximal to the LBB.

Output-dependent subtle changes in QRS morphology with RBBB pattern and short isoelectric stimulus–QRS intervals at very low outputs characterize LBB pacing. Significant lengthening of stimulus to right atrial conduction intervals during RV septal pacing from the anode compared to lead-tip pacing at the LBB region confirms engagement of the conduction system. During RV septal pacing (anodal capture) the conduction occurs through the myocardium initially before engaging the distal Purkinje fibers and then the bundle branches, the His bundle, and the AV node to the atrium. When pacing from the lead tip, conduction occurs directly through the LBB, His bundle, and AV node to the atrium, resulting in shorter conduction times (Figure 1). Because the lead tip and ring electrodes straddle the RV and left ventricular (LV) myocardium (Supplemental Figure 1), bipolar pacing can result in 3 different QRS morphologies owing to fusion between RV septal, LV septal, and LBB capture.

LBB pacing provides significant advantage in patients with conduction disease at the distal His bundle by providing a stable and low capture threshold with adequate sensing amplitude compared to HBP, wherein the pacing thresholds are generally higher and associated with poor sensing. The anatomy and distribution of LBB network in the LV septum has been well described by Tawara in 1906.[5] The left bundle and its branches provide a larger target for physiologic pacing compared to the very narrow target offered by the His bundle. By predominant activation of the left ventricle via the native His-Purkinje system, there is minimal LV dyssynchrony[4] during LBB pacing. As the right ventricle is predominantly activated via myocardial conduction (lack of direct conduction through RBB), RV dyssynchrony may be present compared to HBP. However, interventricular dyssynchrony may theoretically be reduced owing to simultaneous capture of RV and LV myocardium during bipolar pacing. LBB pacing may be a potential alternative to HBP in patients with LBBB and cardiomyopathy, especially when biventricular pacing is not feasible. Several aspects of this novel technique need further investigation. Concern for potential thromboembolism (should the lead penetrate the LV septum) and risk for iatrogenic ventricular septal defect in patients requiring lead extraction remain with this technique and will need further careful evaluation.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2019.01.006.

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