Comparing different activation patterns in a physiological pacing case: Insights from high-resolution mapping

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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. Physiological pacing, including His bundle pacing (HBP) and left bundle branch pacing (LBBP), has recently been shown to have better synchronization of the left ventricle, and potentially reduces heart failure.[1,2] However, high-resolution ventricular activation patterns during different pacing modes have been seldom reported.

KEY TEACHING POINTS

- High-resolution mapping could be used to demonstrate detailed ventricular activation patterns during different pacing modes.
- High-resolution mapping showed that physiological pacing, including His bundle pacing and left bundle branch pacing, has similar activation patterns.
- High-resolution mapping proved that physiological pacing has better left ventricular electrical synchronism when compared with conventional pacing.

Case report

An 85-year-old female patient, presenting with persistent atrial tachycardia (AT) and intermittent atrioventricular block, was referred for AT ablation and physiological pacing. The patient was diagnosed with AT for more than 1 year, and now intermittently presents with dizziness. An electrocardiogram (ECG) monitor reported a long R-R interval of 8 seconds. A cardiac ultrasound examination suggested an enlarged left atrial diameter of 43 mm and a normal left ventricular (LV) ejection fraction. The patient was orally anticoagulated for >3 weeks. We attempted to perform the AT ablation and then implant a pacemaker with physiological pacing. A left atrial contrast-enhanced computed tomography was performed to exclude atrial thrombus before the procedure. The activated clotting time was maintained for >300 seconds during the AT ablation and following mapping.

The 12-lead ECG during AT presented with a biphasic p wave in the inferior leads and a positive p wave in V_1. A decapolar catheter was placed in the coronary sinus (CS) and a quadripolar catheter in the RV apex. The AT cycle length was 240 ms, and the activation sequence of the A wave on the CS catheter was almost simultaneous. High-resolution mapping with the Rhythmia 3-dimensional electroanatomic mapping system (Boston Scientific Corp, Marlborough, MA) was performed in both the right and the left atria with the Orion 64-polar mini basket catheter. Activation mapping revealed a focal or microreentrant mechanism originating from the left atrial anterior wall close to a dense scar. A single radiofrequency application successfully terminated the AT (Supplemental Figure 1). Additional ablation was applied adjacent to the site of termination.

Baseline LV activation mapping was initially performed during CS pacing with 500 ms cycle length for a stable rhythm. The LV activation map suggested that the endocardial activation time was 80 ms and the activation wavefront originated from the middle anterior septum and went backward to the mitral annulus (Figure 1 and Supplemental Video 1).

Subsequently, physiological pacing was performed. We punctured the left axillary vein twice and placed 2 delivery sheaths (SafeSheath; Pressure Products Medical Supplies, San Pedro, CA). Using a dual-lead technique, 2 pacing leads (3830, SelectSecure; Medtronic, Minneapolis, MN) were successfully implanted at the His bundle region and deep in

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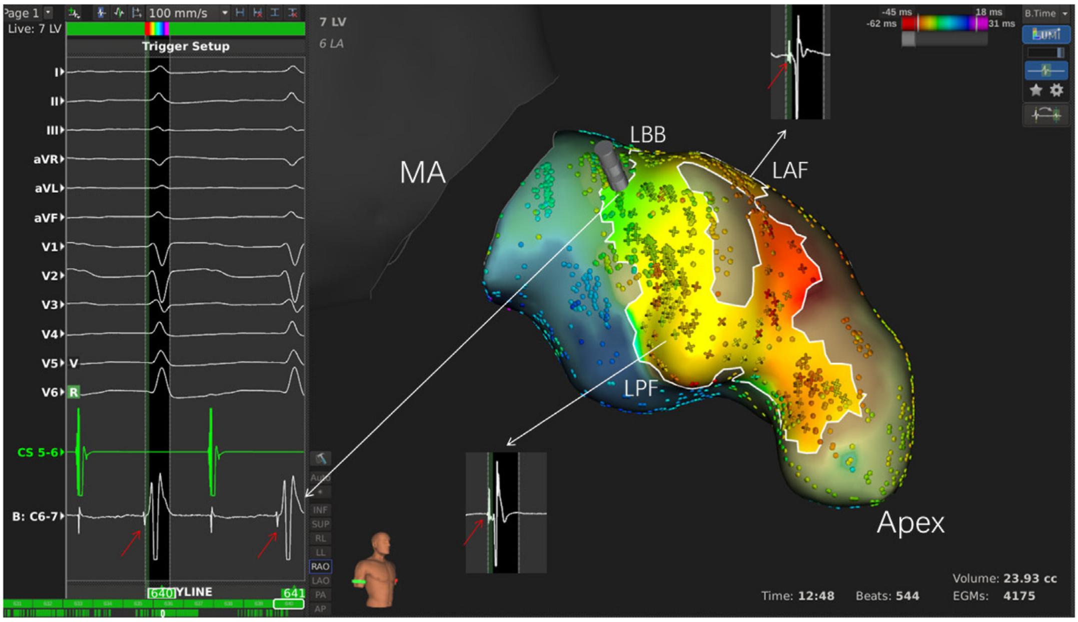

Figure 1 Baseline left ventricular (LV) activation mapping. Baseline LV high-resolution activation mapping was performed during coronary sinus pacing. The color-coded map revealed the LV activation sequence from the middle and anterior septum backward toward the base. The Lumipoint software highlighted the His-Purkinje potential distribution area. Red arrows indicate the potentials of the left bundle branch or fascicle. LAF = left anterior fascicular; LBB = left bundle branch; LPF = left posterior fascicular; MA = mitral annulus.

the interventricular septum at the left bundle branch (LBB) region, respectively, through C315 His delivery sheaths (Medtronic, Minneapolis, MN) (Figure 2A and 2B). Sharp His and LBB potentials were recorded on these 2 pacing leads (Figure 2C and 2E). Direct LBB capture was confirmed by recording the retrograde His potential. The discrete local ventricular potential on the LBB lead suggested selective LBB capture (Figure 2F).[3]

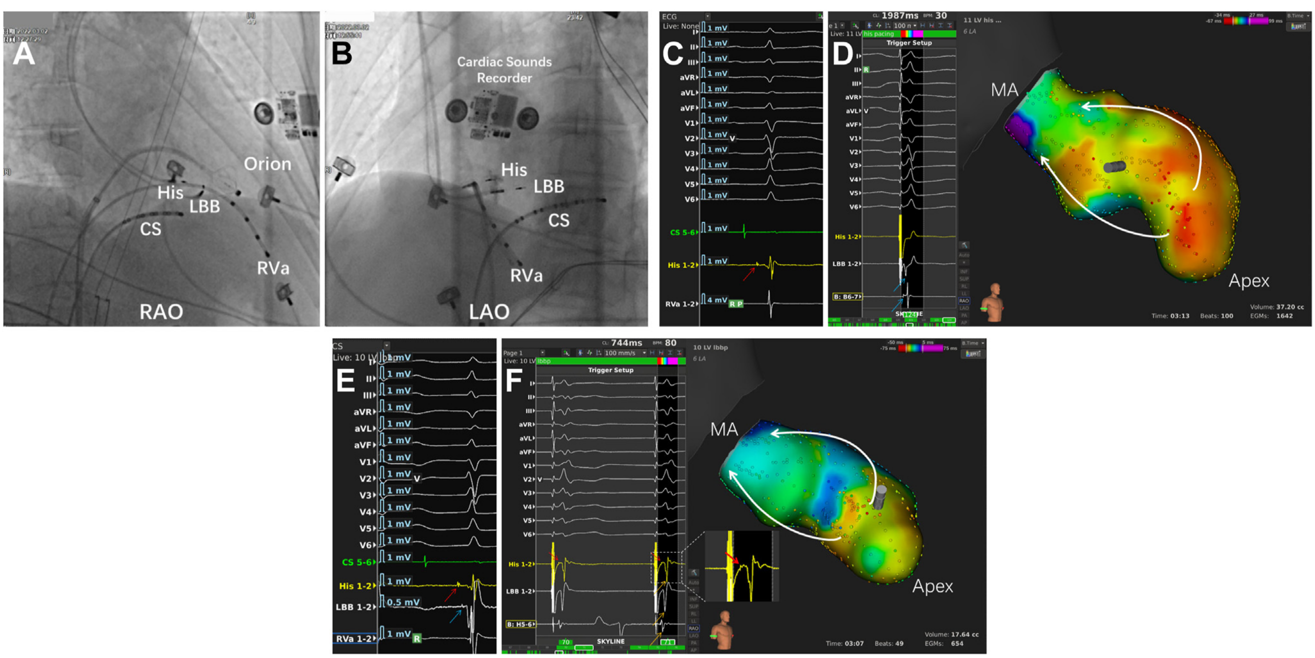

Figure 2 Left ventricle (LV) activation mapping during His bundle pacing (HBP) and left bundle branch (LBB) pacing. **A, B:** Fluoroscopy in right anterior oblique (RAO) and left anterior oblique (LAO) views shows the catheters and pacing leads in different positions. **C:** A sharp His potential (*red arrow*) was recorded on the pacing lead in sinus rhythm. **D:** The LV was mapped during HBP. The 12-lead electrocardiogram (ECG) morphology was similar to that of sinus rhythm. LBB potentials (*blue arrows*) could also be recorded on the LBB pacing lead and Orion mapping catheter. The activation map demonstrated the wavefront conducted from the middle and anterior septum backward toward the base. **E:** A sharp LBB potential (*blue arrow*) was recorded on the pacing lead in sinus rhythm. The LV was mapped during LBB pacing. The 12-lead ECG presented complete right bundle branch block morphology. The retrograde His potential (*red arrow*) confirmed direct LBB capture. The discrete local ventricular potential on the LBB lead (*orange arrows*) and their backward activation sequence further suggested the selective LBB capture. CS = coronary sinus; MA = mitral annulus; RVa = right ventricular apex.

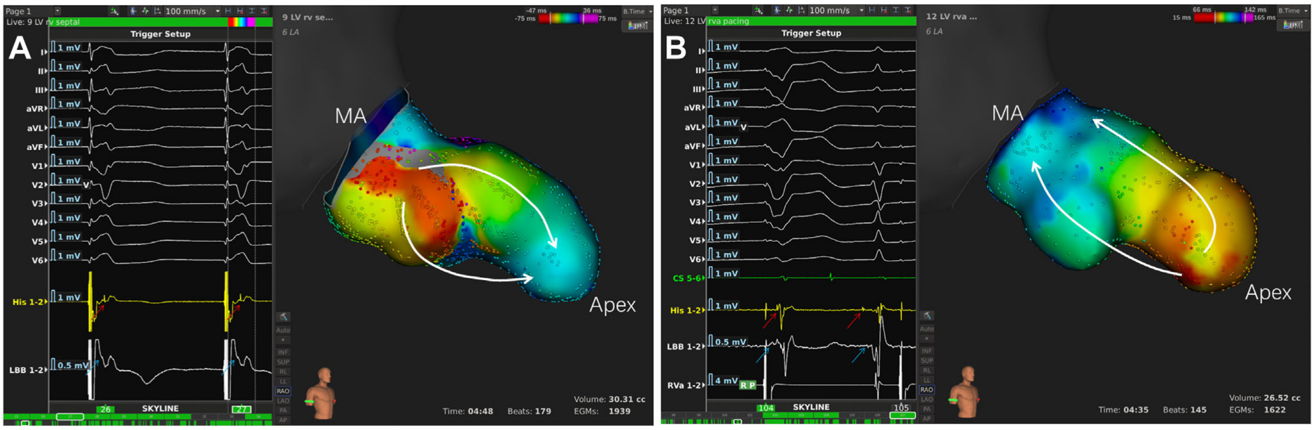

Figure 3 Left ventricular (LV) activation mapping during right ventricular (RV) high septal pacing and right ventricular apex (RVa) pacing. **A:** LV activation mapping during RV high septal pacing. The 12-lead electrocardiogram (ECG) presented left bundle branch block morphology. Note that the His lead could record retrograde sharp His potentials (*red arrows*). The activation map demonstrated the wavefront conduction from the base (mitral annulus; MA) toward the apex. **B:** LV activation mapping during RVa pacing. The 12-lead ECG presented with a very wide QRS morphology. Note that the His and left bundle branch (LBB) potentials (*red and blue arrows*) could be seen during both RVa pacing and sinus rhythm (the second beat). The activation map demonstrated the wavefront conduction from the apex backward toward the base (MA).

LV endocardial activation mapping was performed by the Orion catheter via trans-septal approach during HBP, LBBP, RV high septal pacing (from the LBB ring electrode), and RV apex pacing (from the quad catheter) (Figures 2 and 3). LV activation propagations at different pacing sites are demonstrated in Supplemental Videos 2–5. The same pacing parameters of 3.0 V / 0.5 ms @ 80 beats/min were applied in all ventricular pacing positions. The electrophysiological characteristics during different sites' pacing are compared in Supplemental Table 1.

His and LBB bundle capture were confirmed again according to previously published criteria.[4,5] Owing to the better threshold of pacing (0.8 V / 0.5 ms vs 2.8 V / 0.5 ms), the LBB electrode was eventually retained. The His lead was removed and another active pacing lead (5076, SelectSecure; Medtronic, Minneapolis, MN) was placed in the right atrial appendage with acceptable parameters (capture threshold 1.0 V / 0.5 ms, sensitivity 2.4 mV, impedance 536 Ω). To finish, the 2 leads were connected to a DDDR pacemaker (A3DR01, Medtronic).

At 1 month follow-up, the patient remained in sinus rhythm with no antiarrhythmic medications. Standard parameters of DDDR pacemakers were still used.

Discussion

Studies have demonstrated the feasibility, safety, and favorable clinical outcomes of physiological pacing.[1,2] Upadhyay and colleagues[6] used linear multielectrode catheters to assess for the presence and level of complete conduction block in patients with LBB block patterns in HBP but not LBBP patients. We used high-resolution 3-dimensional mapping technology to identify the accurate LV activation patterns in different rhythms and provided further evidence of the benefits of physiological pacing. Similar descriptions have been reported using noninvasive global epicardial electrogram electrocardiographic imaging mapping.[7,8] This case, however, appears to be the first to illustrate activation patterns in vivo with high-density endocardial mapping.

The high-resolution LV mapping during CS pacing (intrinsic ventricular rhythm) showed that the earliest activation sites were located at the middle septum and distributed extensively (Figure 1). This suggested the myocardium can contract synchronously. The backward activation sequence could meet the needs of extruding blood into the outflow tract. The detailed activation sequence (Figure 2) and LV activation time (Supplemental Table 1) in the HBP and LBBP were similar to those in CS pacing. This suggests that both the HBP and LBBP might have almost the same LV electrical synchronism as compared with the intrinsic ventricular rhythm. Although its QRS duration was relatively narrow, the RV high septal pacing demonstrated a reverse LV activation sequence (Figure 3) and the longest LV activation time (Supplemental Table 1). The RV apex pacing presented the longest QRS duration and relatively long LV activation time, although its activation sequence was backward. These conventional pacing modes demonstrated different characteristics either in electrical synchronism or in activation orientation.

Conclusion

High-resolution mapping showed that physiological pacing, including HBP and LBBP, has better LV electrical synchronism when compared with conventional pacing.

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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.hrcr.2023.08.005.

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