

A case of pacing-induced cardiomyopathy dramatically reversed by left bundle branch pacing in one week



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Introduction

Right ventricular pacing is a traditional pacing modality for patients diagnosed with atrioventricular block. However, long-term right ventricular pacing may lead to pacing-induced cardiomyopathy (PICM) characterized by ventricular systolic dyssynchrony, deteriorative left ventricular systolic function, and symptoms of heart failure. It was reported that 10%–20% of patients have developed PICM after pacemaker implantation.^{1–3} Cardiac resynchronization therapy is the most common treatment for PICM, although it was reported with higher economic cost and uncertain prognosis.⁴ Recently, left bundle branch pacing (LBBP) has emerged as a novel physiological pacing modality and has been proposed as an alternative treatment for PICM.⁵ We present a case of PICM dramatically reversed by replacing the lead to the left bundle branch (LBB) region within 1 week.

Case report

An 86-year-old Chinese woman with high-degree atrioventricular block was implanted with a dual-chamber pacemaker in October 2018. The ventricular electrode was placed in the right ventricular outflow tract septum. She complained about exertional dyspnea 6 months later with no chest pain (May 2019). A history of coronary heart disease was denied, and previous coronary computed tomography angiography was negative. Pacemaker programming demonstrated 92% pacing rate, suggesting high pacemaker dependence. The echocardiography revealed that left ventricular ejection fraction (LVEF) decreased from preoperative 61% to 35% and

KEY TEACHING POINTS

- Pacing-induced cardiomyopathy (PICM) refers to the deterioration of left ventricular systolic function in patients with normal left ventricular ejection fraction under the condition of a chronic and high burden of right ventricular pacing.
- PICM could be reversed by left bundle branch pacing (LBBP) lead replacement dramatically within 1 week. LBBP might be a promising method to treat patients with PICM.
- An important mechanism of PICM is that electrical dyssynchrony led to left ventricular mechanical dyssynchrony.
- When the electrical dyssynchrony was corrected by LBBP lead replacement, the mechanical synchrony could be obviously improved, and cardiac function was reversed rapidly.

left ventricular internal diameter at end-diastole increased from preoperative 4.39 cm to 4.89 cm. The 12-lead electrocardiogram showed atrial sensing ventricular pacing rhythm and pacing QRS duration was 156 ms (Figure 1). B-type natriuretic peptide levels increased to 1125.2 pg/mL compared with 133.7 pg/mL before implantation. The patient was diagnosed with PICM and was treated with sacubitril/valsartan (ARNI), bisoprolol, furosemide, and spironolactone. The cardiac function had not improved after 1 year of optimized drug treatment, LVEF was remained as 36%, and left ventricular internal diameter at end-diastole increased to 5.39 cm in January 2020, and the symptoms were unrelieved. The mechanical dyssynchrony was assessed by septal-to-posterior wall motion delay (SPWMD, assessed by M-mode) of 141 ms, interventricular mechanical delay (IVMD, assessed by tissue Doppler spectrum) was 73 ms, the proportion of left ventricular filling time in a cardiac cycle (T(E-A)/T(E-E),

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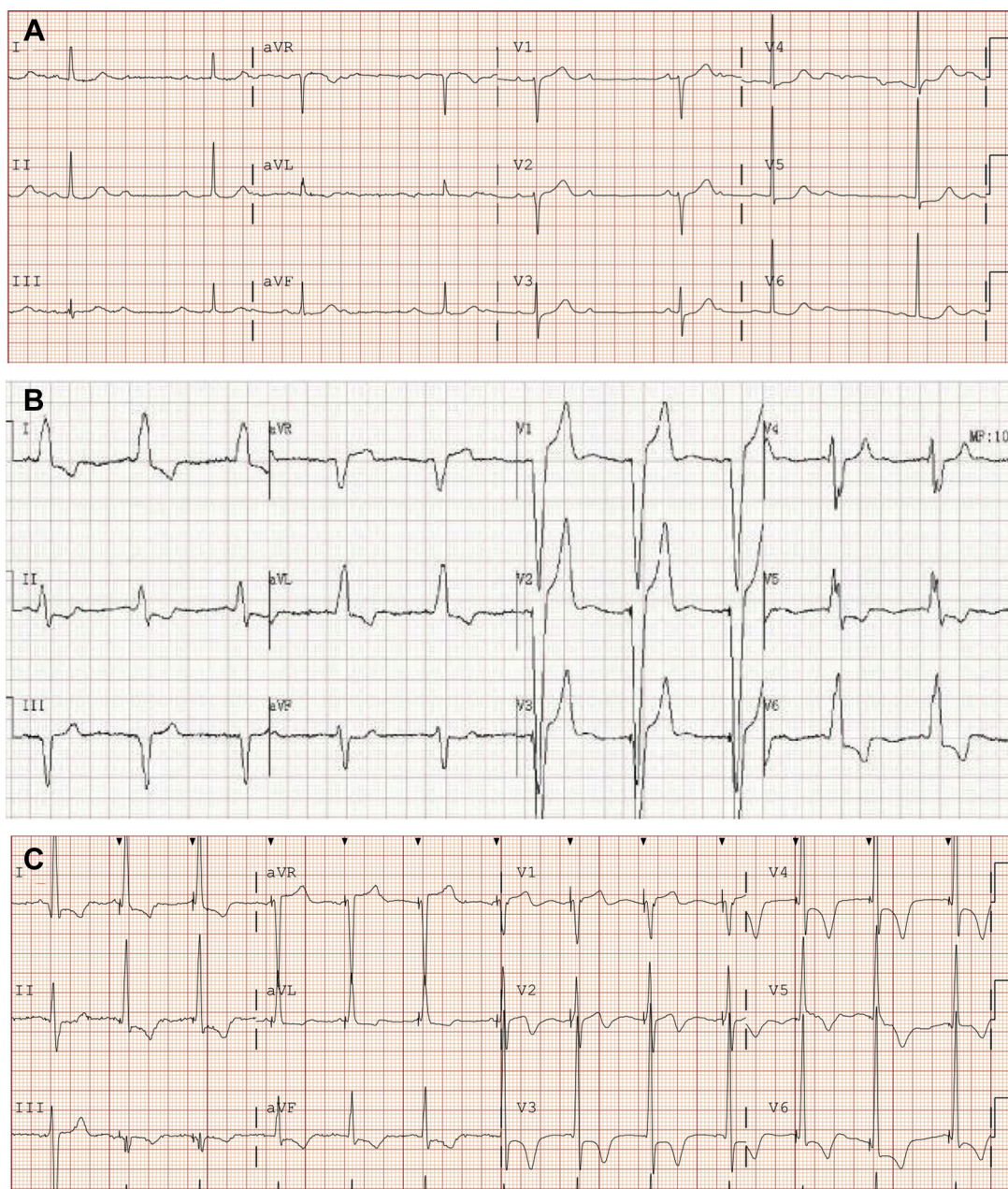


Figure 1 Electrocardiogram (ECG) before and after operation. **A:** ECG showed the native QRS duration was 88 ms before a pacemaker implantation. **B:** ECG showed complete left bundle branch block (CLBBB) with pacing QRS duration of 152 ms before lead replacement. **C:** ECG showed the left bundle branch pacing QRS duration was 105 ms after replacement and CLBBB was corrected.

assessed by tissue Doppler spectrum) was 32.5%, systolic dyssynchrony index (SDI, assessed by real-time 3-dimensional echocardiography) was 14.8% (Table 1).

The ventricular lead replacement was performed on May 23, 2020. The left subclavian vein was shown slightly narrowed by the venography. The axillary vein was punctured, and a 9F sheath was introduced to dilate the left subclavian vein and replaced by a 7F sheath. A Medtronic (Minneapolis, MN) C315HIS sheath was advanced through the 7F sheath to the right ventricle over a guidewire, and then a SelectSecure 3830 pacing lead was implanted to map the His bundle potential; the His-ventricular interval was prolonged and infra-Hisian block was considered, then the His bundle area

was set as a marker for LBBP lead implantation. The 3830 electrode was initially pushed to the position approximately 1–2 cm away from the distal His bundle area in the right ventricular septum along the line between the His bundle site and right ventricle apex in the right anterior oblique (30°) fluoroscopic view. The 3830 lead was screwed at the position where the paced QRS morphology demonstrated a “w” pattern with a notch at the nadir of QRS in lead V₁. When the lead was successfully placed to the left ventricular septal subendocardium in the LBB region (Figure 2), the paced QRS morphology changed to a right bundle branch block pattern. P potential could be recorded in the intracardiac electrogram from LBBP; the interval of the potential to QRS was 25 ms and

Table 1 Echocardiography results preoperation and 3 days and 1 week after lead replacement

	Preoperation	3 days postoperation	1 week postoperation
LVEF (%)	36.0	49.0	61.4
LVIDd (cm)	5.39	5.02	4.58
Interventricular dyssynchrony			
SPWMD (ms)	141	49	40
SDI (%)	14.8	11.36	2.58
Intraventricular dyssynchrony			
IVMD (ms)	73	21	18
Atrioventricular dyssynchrony			
T(E-A)/T(E-E) (%)	32.5	57.1	47.5

IVMD = interventricular mechanical delay; LVEF = left ventricular ejection fraction; LVIDd = left ventricular internal diameter at end-diastole; SDI = systolic dyssynchrony index; SPWMD = septal-to-posterior wall motion delay; T(E-A)/T(E-E) = the proportion of left ventricular filling time in the cardiac cycle.

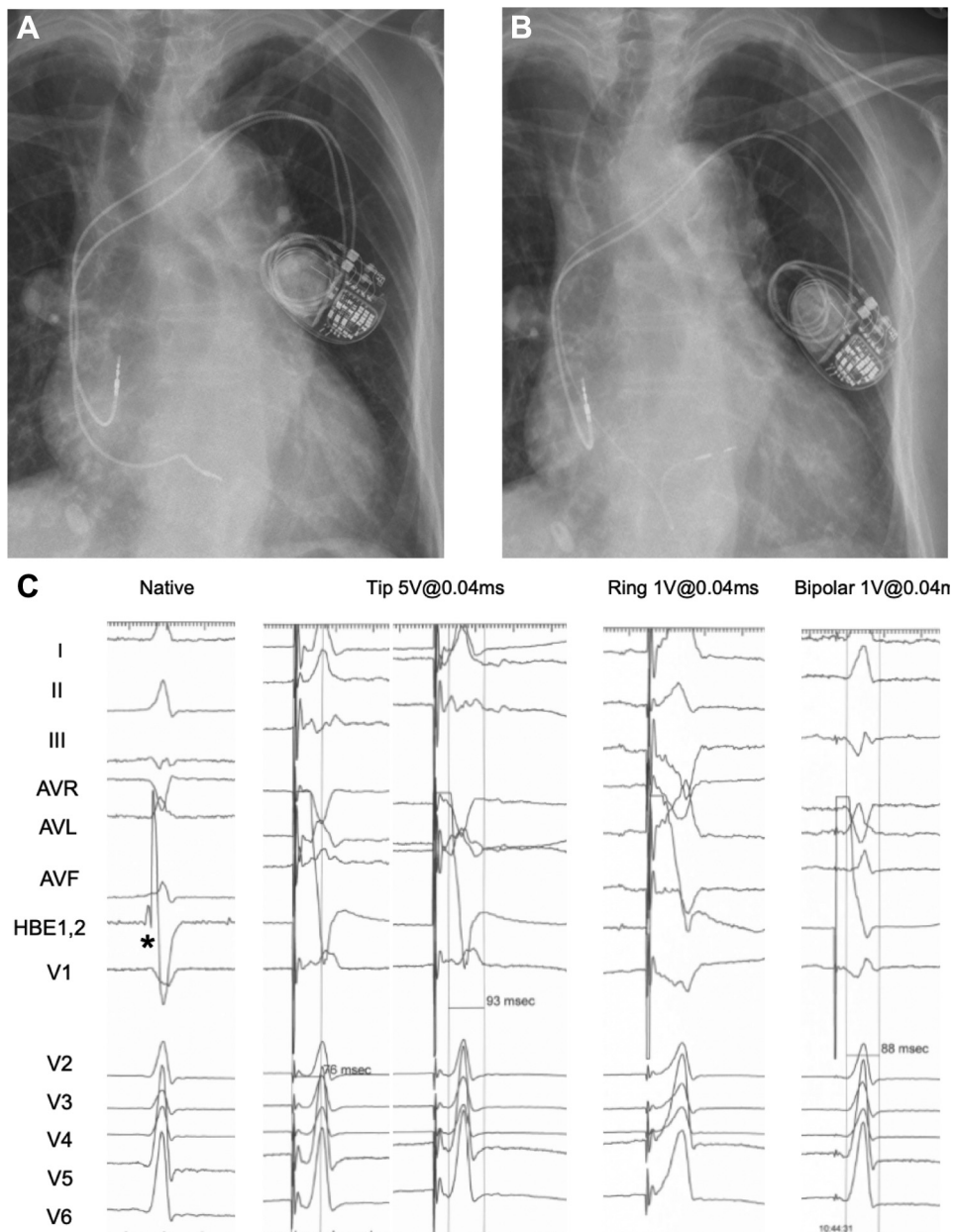


Figure 2 Fluoroscopic location of the left bundle branch (LBB) pacing lead. **A:** Before the lead replacement, the ventricular lead was placed in the interventricular septum. **B:** After the lead replacement, the location of the ventricular lead was changed to the LBB area. **C:** Twelve-lead electrocardiogram and intracardiac electrograms. The asterisk in the figure shows P potential and injury potential. Pacing at 5 V @ 0.04 ms; pacing stimulus-to-left ventricular activation time was 76 ms; QRS duration was 93 ms. Bipolar pacing at 1 V @ 0.04 ms; paced QRS duration was 88 ms.

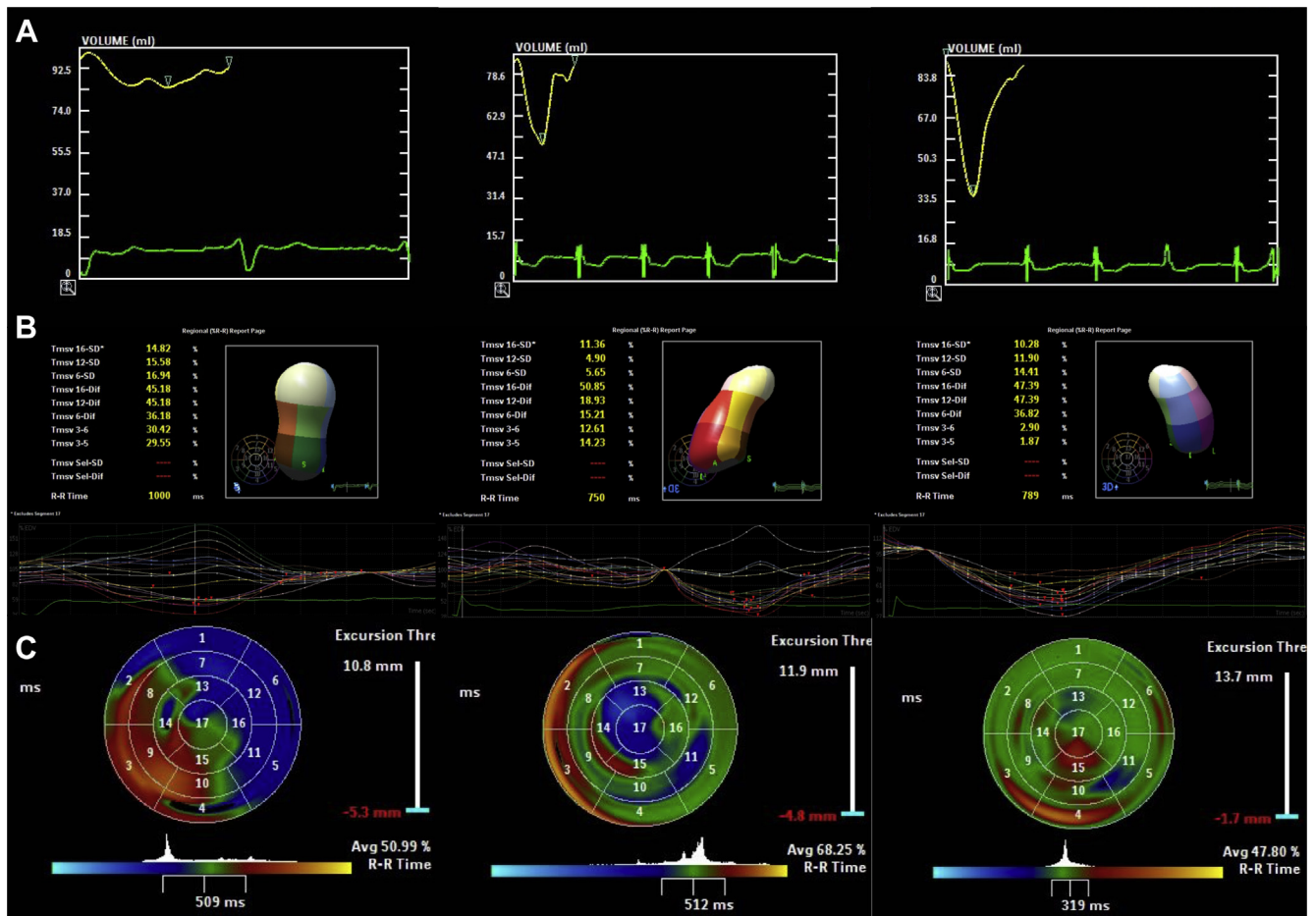


Figure 3 Evaluation of cardiac systolic synchrony by real-time 3-dimensional echocardiography (RT-3DE). **A:** Three-dimensional volume time curve showed that the peak time of volume was significantly shortened 3 days (middle) and 1 week after operation (right), and the peak value increased. **B:** The 3D left ventricle model and 17 segments. For each volumetric segment, it is possible to access time-volume curves and time to minimum systolic volume (red dots). The time-volume curves were dyssynchrony at the baseline (left), whereas the segmental time-volume curves were more synchronous 3 days after lead replacement (middle) and got much better in 7 days after lead replacement (right). **C:** Parametric image, using color-coding (blue indicating early activation and orange-red late activation), showing that the anterior and anterolateral left ventricle regions from apical to basal are the latest activated before replacement (polar plot on the left). Three days after replacement, the area of green color significantly increased, indicating regions where delayed activation decreased and synchrony improved (polar plot in the middle); these results also appeared 4 days later, with almost overall green color (polar plot on the right).

the pacing stimulus-to-left ventricular activation time (Stim-LVAT) was 76 ms, indicating the tip of the lead reached the LBB area. The parameters we accessed in the operation showed the pacing threshold was 0.4 V @ 0.4 ms, R wave was 10.6 mV, and impedance was 600 Ω (Figure 2). Electrocardiography showed the paced QRS duration was significantly shortened from 152 ms to 105 ms after the lead replacement (Figure 1).

An echocardiography was performed 3 and 7 days after operation. LVEF increased to 49%, SPWMD was 49 ms, IVMD was 21 ms, and T(E-A)/T(E-E) was 57.1% on the third day. Seven days after the operation, echocardiography was repeated and showed LVEF increased to 61.4%, SPWMD decreased to 40 ms, LVMD decreased to 18 ms, and T(E-A)/T(E-E) increased to 47.5% (Table 1). The real-time 3-dimensional echocardiography (RT-3DE) showed SDI decreased to 11.36% (3 days) and 2.58% (7 days) (Figure 3), indicating that myocardial systolic synchrony and left ventricular systolic function were significantly

improved within 1 week. In addition, the exercise tolerance was assessed by a 6-minute walk test, which was 339 meters before operation and increased to 379 meters 1 week later. Simultaneously, the Minnesota Heart Failure Quality of Life scale score decreased from 29 to 12, indicating that the patient’s quality of life was significantly enhanced.

Discussion

Definition and mechanism of PICM

PICM refers to the deterioration of left ventricular systolic function in patients with normal LVEF under the condition of a chronic and high burden of right ventricular pacing. The LVEF criteria were rarely standardized; most studies applied LVEF of either ≤40% or 50%,¹⁻³ while an absolute reduction of at least 5%–10% was also emphasized.³ The reported patient received high-burden (92%) right ventricular pacing with wide paced QRS (152 ms), which were identified

as risk factors for PICM,⁶ and the LVEF decreased from 61% to 35% and accompanied by symptoms of heart failure.

Evaluation of cardiac systolic synchrony by echocardiography

Two-dimensional echocardiography was commonly used to assess the mechanical synchrony parameters, such as SPWMD, IVMD, and T(E-A)/T(E-E), with some limitations.⁷ As an important synchrony parameter of RT-3DE, SDI was defined as the standard deviation of time to minimum systolic volume for all 16 left ventricle segments and corrected for the R-R duration.⁸ Studies have demonstrated that evaluation of ventricular systolic dyssynchrony by RT-3DE was practical and repeatable.^{9,10} In this case, we evaluated the left ventricular systolic synchrony by the bull's-eye maps, SDI, and SPWMD, and revealed the improvement of interventricular synchrony; decreased IVMD, indicating the improving intraventricular synchrony; and increased T(E-A)/T(E-E), indicating the better atrioventricular synchrony. Therefore, the mechanical synchrony was significantly improved and consistent with the symptom relief, 6-minute walking test, and quality-of-life scale assessment.

Reverse of PICM by LBBP

Various methods have been tried to reverse PICM. Adjusting pacing algorithms to reduce the right ventricular pacing burden showed no significant improvement in clinical outcomes.¹¹ Cardiac resynchronization therapy could improve the cardiac function of PICM patients,^{2,12} but it has many shortcomings, such as increased economic cost, more complications, and being restricted by congenital anatomy of the coronary vein.⁴ His-Purkinje system pacing is a novel physiological pacing method that can directly capture the conduction system and ensure normal ventricular activation order with narrower QRS duration and better ventricular systolic asynchrony.^{13,14} In this case, LBBP lead replacement was performed, and cardiac systolic synchrony and LVEF were significantly improved within 3 days and almost totally recovered dramatically within 1 week. It was far beyond our past experience, which indicated it may take almost 6 months to 1 year to recover after implantation. Therefore, LBBP might be a promising method to treat patients with PICM.

Mechanism of cardiac systolic function recovered dramatically

An important mechanism of PICM is that electrical dyssynchrony led to left ventricular mechanical dyssynchrony. In

this case, electrical dyssynchrony occurred after pacemaker implantation. With a high percentage of traditional right ventricular pacing, typical heart failure symptoms occurred, and the systolic function was decreased. When the electrical dyssynchrony was corrected by LBBP lead replacement, the mechanical synchrony could be obviously improved, and cardiac function was reversed rapidly. This case showed a new perspective of the therapy of PICM, which can improve cardiac function rapidly by correcting electrical dyssynchrony and was a challenge to conventional thinking of the pathogenesis of heart failure.

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