

ORIGINAL ARTICLE



Application Study of Left Bundle Branch Pacing in Single-Chamber Cardioverter Defibrillator Implantation

Jiahui Zheng¹, Yawen Zhang², Wensheng Zhu³, Yanguang Mu¹, Shixun Wang¹

¹Department of Cardiology, Weifang People's Hospital (The First Affiliated Hospital of Shandong Second Medical University), Weifang, Shandong, China

²Department of Electrocardiography, Weifang People's Hospital (The First Affiliated Hospital of Shandong Second Medical University), Weifang, Shandong, China

³School of Clinical Medicine, Shandong Second Medical University, Weifang, China,

Department of Cardiology, Weifang People's Hospital (The First Affiliated Hospital of Shandong Second Medical University), Weifang, Shandong, China

*Corresponding Author: Shixun Wang

Keywords: Cardioverter-defibrillator (ICD), left bundle branch pacing (LBBP), heart failure(HF)

Introduction

The implantation of implantable cardioverter-defibrillators (ICDs) currently utilizes traditional right ventricular apex pacing and low ventricular septal pacing. However, these pacing modes can lead to electrical and mechanical dyssynchrony, particularly in patients who are pacing-dependent, significantly increasing the risk of heart failure exacerbation [1]. Currently, His-Purkinje System Pacing (HPCSP), which includes left bundle branch pacing (LBBP) and His bundle pacing (HBP), can achieve synchronized electrical conduction and mechanical movement of the heart. This approach significantly shortens the duration of the QRS complex under pacing and markedly improves the clinical prognosis of patients [2, 3]. LBBP is simpler and has a more stable threshold than HBP. Clinical studies have demonstrated the feasibility and safety of LBBP, showing it to have a relatively low pacing threshold, infrequent complications, and a high procedural success rate [4, 5]. However, there are very few clinical studies on the application of LBBP in ICD implantation. The purpose of this study is to analyze the feasibility, effectiveness, and advantages of LBBP in ICD implantation, with the aim of providing a reference for its

clinical application.

Object and Method

1.1 Research Subjects:

Patients who underwent single-chamber ICD implantation in the cardiology department of Weifang People's Hospital from August 2022 to May 2023 were selected as research subjects and were continuously enrolled. Inclusion criteria: Age ≥ 18 years, meeting the indications for ICD, including secondary and primary prevention of malignant arrhythmias. Exclusion criteria: Within 30 days of acute myocardial infarction; patients with other serious organic diseases; patients with an expected lifespan of less than 6 months. This study was conducted in accordance with the principles of the Helsinki Declaration and was approved by the Ethics Committee of Weifang People's Hospital. Patients signed informed consent forms.

1.2 Method:

The patient's 12-lead electrocardiogram (ECG) and intracardiac electrophysiological map were recorded. The His bundle sheath (C315, Medtronic Corporation) and Medtronic 3830

pacing lead (SelectSecure, Medtronic Corporation) were introduced through the left subclavian or axillary vein. Following Huang's steps [6], the His bundle area was determined [7] based on the mapped His bundle potential and used as an anatomical marker. A line was drawn from the His bundle to the apex, with a distance of 1.0-1.5 cm from the His bundle as the starting point for left bundle branch pacing. With the support of the C315 sheath, the Medtronic 3830 pacing lead tip was rotated vertically into the interventricular septum. During this period, the QRS morphology of lead V1 was monitored (transitioning from a notched "w" shape to a right bundle branch block shape), and pacing parameters (pacing threshold, lead impedance, and R-wave amplitude) were tested before completing left bundle branch pacing (Figure 1-a,

b). The criteria for successful left bundle branch pacing were: ① Pacing in a right bundle branch block pattern; ② Tracing the left bundle branch potential; ③ Sudden shortening of stimulus-to-peak LV activation time (pLVAT), while maintaining the shortest fixation; ④ Selective left bundle branch pacing. The patient's 3830 lead was inserted into the ICD pulse generator's IS-1 RV port, while the IS-1/DF-1 6935 lead was implanted in the low right ventricular septum and connected to the ICD pulse generator at the DF-1 RV port. The IS-1 B1 connector plug was capped, and the SVC port was blocked with a plug. The defibrillation lead 6935-65 was fixed in the low interventricular septum of the right ventricle (Figure 1-c). The ICD pulse generator used was Medtronic DVBC3D1.

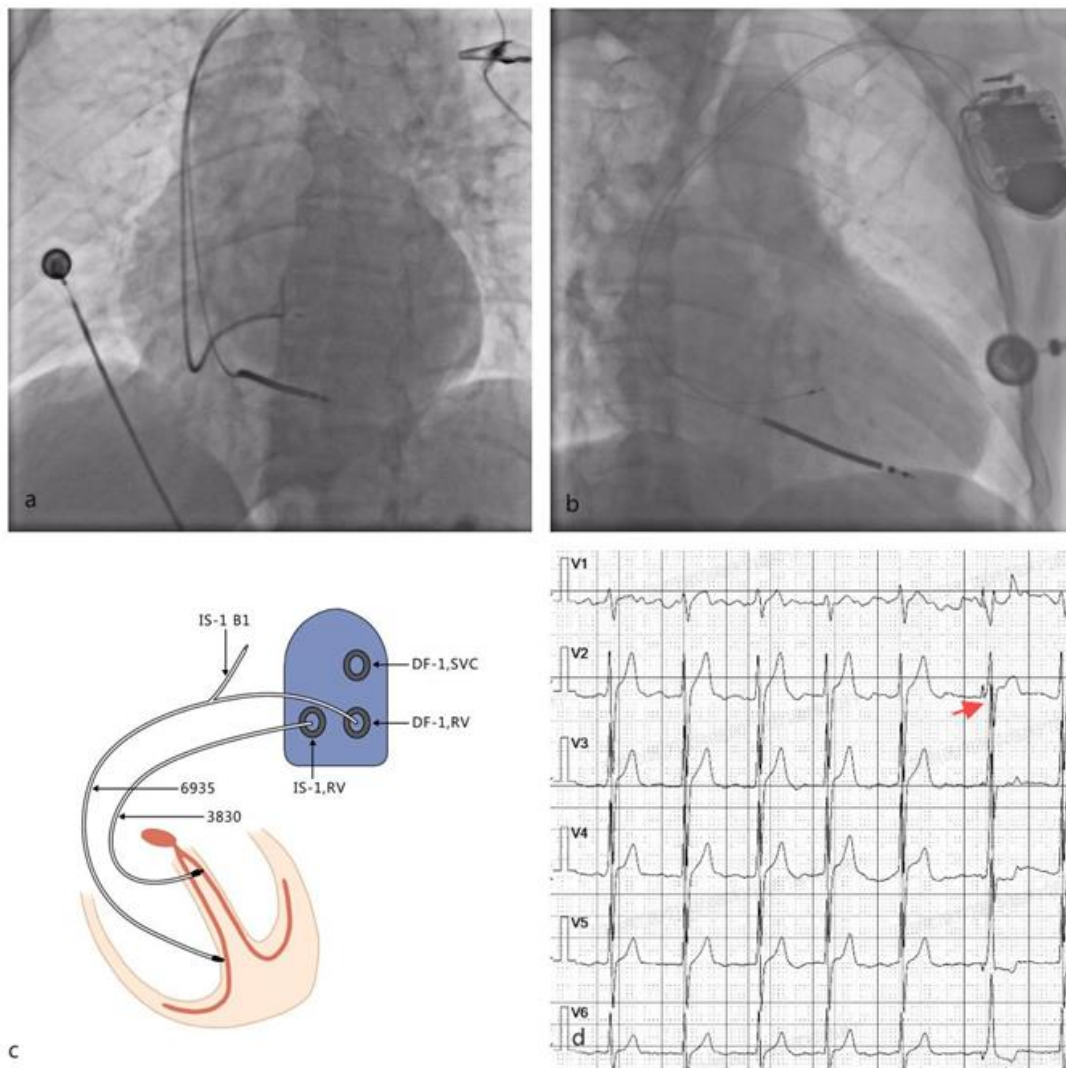


Figure 1 a,b: Left anterior oblique(LAO) and right anterior oblique (RAO) view showed the positions of 3830 lead and 6935 lead.

c: IS-1/DF-1 6935 lead was implanted in low right ventricular septum, IS-1 B1 connector plug was capped, 3830 lead was implanted in the the left bundle branch area and connected to one-chamber ICD impulse generator at IS-1 RV port.

d: The position indicated by the arrow was the electrocardiogram of left bundle branch pacing, the duration of QRS complex is 110ms.

1.3 Observation Indicators:

(1) Baseline Data: Baseline data of patients were collected, including gender, age, ECG findings, and complications [sudden cardiac death (SCD), myocardial infarction, hypertension, diabetes].

(2) Surgical Procedure Related Indicators: The R-wave amplitude, pacing threshold, electrode impedance, defibrillation impedance of the 3830 lead, and 6935-65 defibrillation lead, incidence of surgery-related complications (ventricular septal perforation, lead displacement, bleeding, etc.), and surgical success rate were studied during ICD implantation. The criteria for successful surgery were successful left bundle branch pacing lead and defibrillation lead implantation, stable parameters, and no surgery-related complications.

(3) Follow-up Indicators: ECG, echocardiography, pacemaker parameters, MACE events, duration of QRS complex (dQRS), left ventricular ejection fraction (LVEF), and left ventricular end-diastolic diameter (LVEDD) were followed up. Pacemaker parameters were detected and programmed at 4 weeks, 3 months, 6 months, and 1 year after surgery, mainly to detect pacing threshold, sensing, impedance, defibrillation electrode impedance, and occurrence of arrhythmia events (including ATP treatment program and ICD discharge defibrillation). Patients were followed up for 1-12 months via telephone or routine follow-up after surgery, and the incidence of MACE (SCD, readmission due to heart failure, and death) was recorded.

1.4 Statistical Methods:

SPSS 25.0 software was used for data analysis. First, the Shapiro-Wilk test was applied to assess the normality of all measurement data. Data conforming to a normal distribution are expressed

as mean \pm standard deviation. A paired t-test was used for comparison within groups before and after the intervention, and an independent samples t-test was used for group comparisons. Non-normally distributed data were represented by [M (P25, P75)], and non-parametric rank-sum tests were used for comparison between the two groups. A p-value <0.05 indicates a statistically significant difference.

Results:

2.1 Baseline Data: All 8 patients were male, aged between 44 and 82 years. ECG findings included 3 cases of ventricular tachycardia, 6 cases of atrial fibrillation, 6 cases of frequent premature ventricular contractions, 1 case of sinus node dysfunction, and 1 case of complete left bundle branch block. Complications included 2 cases of myocardial infarction, 5 cases of hypertension, 2 cases of diabetes, and 8 cases of heart failure. All 8 patients underwent single-chamber ICD implantation.

2.2 Surgical Related Indicators and Postoperative Follow-up: ICDs were successfully implanted in all 8 patients with no intraoperative complications. Intraoperative pacing parameters were as follows: [3830 lead: R wave [10.00 (9.00, 13.13)] mV, impedance $801.25 \pm 179.88 \Omega$, threshold [0.88 (0.75, 1.0) V], [6935 lead: R wave 9.0 ± 2.29 mV, threshold 0.9 (0.8 , 1.0) V, and impedance $(499.75 \pm 114.01) \Omega$, defibrillation impedance [56.5 \pm 11.54 Ω], all parameters were within normal ranges. After 6 months of follow-up, all parameters remained stable with no statistically significant differences compared to intraoperative results ($P > 0.05$), as shown in Table 1.

Table 1 parameters during the operation procedure and follow up

	3830 lead (n=8)		DF-1 IS-1 6935 (n=8)	
	During operation	6 months after operation	During operation	6 months after operation

threshold (V)	0.88 (0.75, 1.0)	1.0 (0.75 , 1.0) *	0.9 (0.8 , 1.0)	N
R-wave amplitude (mV)	10.00 (9.0, 13.13)	10.01±3.21*	9.00±2.29	N
impedance(Ω)	801.25 ± 179.88	689.13±57.65*	499.75±114.01	N
impedance of Defibrillation (Ω)	N	N	56.5±11.54	58.75±9.25*

Compare to parameters during the operation * $p > 0.05$

2.3 Patients showed no statistically significant differences in dQRS and LVEDD before surgery and 6 months after surgery (112.88 ± 31.97 vs. 110.50 ± 18.02 ms, $P=0.783$; 65.91 ± 4.87 vs. 65.36 ± 4.20 mm, $P=0.447$). However, 6 months after surgery, the LVEF of the patients was significantly higher than before surgery ($27.88 \pm 9.69\%$ vs. $34.75 \pm 4.74\%$, $P=0.015$).

2.4 Severe arrhythmia attacks and MACE events occurred in 2 cases. One patient experienced persistent ventricular tachycardia, which was terminated by ATP treatment without any obvious symptoms. Another patient developed ventricular fibrillation, which required ICD discharge defibrillation and was admitted for treatment. There was no recurrence of ventricular fibrillation after admission.

Discussion:

The risk of pulseless ventricular tachycardia, ventricular fibrillation, and sudden cardiac death (SCD) is significantly increased in patients with heart failure, especially in those with an $EF \leq 35\%$. ICD implantation is necessary for primary or secondary prevention [8]. The traditional method for ICD implantation involves placing the defibrillation lead in the right ventricular apex or interventricular septum for pacing. However, this approach prolongs the dQRS complex beyond 130 ms, leading to asynchronous ventricular contractions, which can further deteriorate heart function, particularly in heart failure patients [9]. Even when the dQRS is less than 130 ms at the time of ICD implantation or the heart rate exceeds the pacing rate, this often results in a slower heart rate during the progression of heart failure and medication, necessitating a more physiological pacing method.

Currently, biventricular pacing and His-Purkinje Conduction System Pacing (HPCSP) are considered physiological pacing methods, but

most heart failure patients requiring ICD implantation have a narrow QRS complex width (dQRS < 130 ms). The traditional biventricular pacing method (BiV-CRTD) is currently not indicated according to guidelines [8], and CRT-D is expensive. Using left bundle branch pacing (LBBP) for ICD lead implantation can synchronize biventricular contractions within a dQRS of 130 ms [8]. In this study, 8 patients were implanted with a left bundle branch pacing lead using a 3830 lead. The dQRS during pacing was 110.38 ± 13.13 ms, and all parameters remained stable during follow-up. Additionally, the left ventricular ejection fraction was significantly higher during the 6-month follow-up than at the time of implantation ($27.88 \pm 9.69\%$ vs. $34.75 \pm 4.74\%$, $P < 0.05$). Given that patients received optimal anti-heart failure drug treatment before surgery, these findings suggest that LBBP for ICD implantation can significantly improve heart function.

In this study, there was no significant difference in LVEDD between preoperative and postoperative follow-up, which may be related to the small sample size and short follow-up period. Two patients experienced episodes of ventricular tachycardia and fibrillation, which were managed with ATP stimulation and defibrillation discharge, effectively restoring normal heart rhythm. This supports the safety and effectiveness of this treatment method.

Among the 8 patients, 6 had atrial fibrillation with an ejection fraction below 35%, and 4 were pacing-dependent. Previous studies have shown that LBBP is not inferior to biventricular pacing in terms of cardiac resynchronization while ensuring ventricular pacing. Patients with atrial fibrillation typically require only single-chamber pacing due to slow heart rates. This surgical method reduces implantation difficulty and treatment costs, making it a potentially ideal option for ICD implantation using LBBP.

In summary, the application of LBBP in ICD implantation surgery is safe and effective, offering benefits in improving patients' cardiac function and clinical prognosis. However, this study is a single-center observational study with a small patient cohort, and further confirmation is needed through clinical studies involving multiple centers and larger sample sizes.

Additional Information

Disclosure: The authors declare no conflict of interest.

Funding Statement: Accepting Support from Weifang City Science and Technology Development Plan Project (2020YX099).

Data availability statement: Due to the protection of the privacy rights of patient, the data is not published publicly. Contact the corresponding author's email address more clinical data is available on request.

Originality statement: This manuscript has not been published in whole or in part, nor has it been considered for publication elsewhere.

Author contribution statement :

Jiahui Zheng: Conceptualization (lead), Data Curation (lead), Formal Analysis (lead), Writing - Original Draft (lead). **Yawen Zhang:** writing – original draft Preparation (equal); formal analysis (equal); **Wensheng Zhu:** writing – original draft Preparation (equal). **Yanguang Mu:** formal analysis (equal), Data Curation (equal).

Shixun Wang (Corresponding Author): Conceptualization (lead), Funding Acquisition (lead), Resources (lead), Supervision (lead), Writing - Review & Editing (lead).

Patient consent statement : Written informed consent was obtained from the patient to publish

this report in compliance with the journal's patient consent policy.

References:

1. Abdelrahman, M., et al., Clinical Outcomes of His Bundle Pacing Compared to Right Ventricular Pacing. *J Am Coll Cardiol*, 2018. 71(20): p. 2319-2330.
2. Vijayaraman, P., et al., His Bundle Pacing. *J Am Coll Cardiol*, 2018. 72(8): p. 927-947.
3. Chen, X., et al., The feasibility and safety of left bundle branch pacing vs. right ventricular pacing after mid-long-term follow-up: a single-centre experience. *Europace*, 2020. 22(Suppl_2): p. ii36-ii44.
4. Vijayaraman, P., et al., Permanent His-bundle pacing: Long-term lead performance and clinical outcomes. *Heart Rhythm*, 2018. 15(5): p. 696-702.
5. Zanon, F., et al., Permanent His-bundle pacing: a systematic literature review and meta-analysis. *Europace*, 2018. 20(11): p. 1819-1826.
6. Huang, W., et al., A beginner's guide to permanent left bundle branch pacing. *Heart Rhythm*, 2019. 16(12): p. 1791-1796.
7. Padala, S.K., J.A. Cabrera, and K.A. Ellenbogen, Anatomy of the cardiac conduction system. *Pacing Clin Electrophysiol*, 2021. 44(1): p. 15-25.
8. Zeppenfeld, K., et al., 2022 ESC Guidelines for the management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. *Eur Heart J*, 2022. 43(40): p. 3997-4126.
9. Kiehl, E.L., et al., Incidence and predictors of right ventricular pacing-induced cardiomyopathy in patients with complete atrioventricular block and preserved left ventricular systolic function. *Heart Rhythm*, 2016. 13(12): p. 2272-2278.