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CLINICAL RESEARCH

The feasibility and safety of left bundle branch pacing vs. right ventricular pacing after mid-long-term follow-up: a single-centre experience

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Aims The aim of this study is to prospectively assess the feasibility and safety of left bundle branch pacing (LBBP) when compared with right ventricular pacing (RVP) during mid-long-term follow-up in a large cohort.

Methods and results Patients ($n = 554$) indicated for pacemaker implantation were prospectively and consecutively enrolled and were non-randomized divided into LBBP group and RVP group. The levels of cTnT and N-terminal pro-B type natriuretic peptide were measured and compared within 2 days post-procedure between two groups. Implant characteristics, procedure-related complications, and clinical outcomes were also compared. Pacing thresholds, sensing, and impedance were assessed during procedure and follow-up. Left bundle branch pacing was feasible with a success rate of 94.8% with high incidence of LBB potential (89.9%), selective LBBP (57.8%), and left deviation of paced QRS axis (79.7%) with mean Sti-LVAT of 65.07 ± 8.58 ms. Paced QRS duration was significantly narrower in LBBP when compared with RVP (132.02 ± 7.93 vs. 177.68 ± 15.58 ms, $P < 0.0001$) and the pacing parameters remained stable in two groups during 18 months follow-up. cTnT elevation was more significant in LBBP when compared with RVP within 2 days post-procedure (baseline: 0.03 ± 0.03 vs. 0.02 ± 0.03 ng/mL, $P = 0.002$; 1 day post-procedure: 0.13 ± 0.09 vs. 0.04 ± 0.03 ng/mL, $P < 0.001$; 2 days post-procedure: 0.10 ± 0.08 vs. 0.03 ± 0.08 ng/mL, $P < 0.001$). The complications and cardiac outcomes were not significantly different between two groups.

Conclusion Left bundle branch pacing was feasible in bradycardia patients associated with stable pacing parameters during 18 months follow-up. Paced QRS duration was significantly narrower than that of RVP. Though cTnT elevation was more significant in LBBP within 2 days post-procedure, the complications, and cardiac outcomes were not significantly different between two groups.

Keywords Left bundle branch pacing • Right ventricular pacing • Feasibility • Follow-up

Introduction

Right ventricular pacing (RVP) is a classical ventricular pacing strategy and its clinical utility has been demonstrated over 60 years. However, RVP, pacing at endomyocardium rather than conduction system, is related to increased risk of atrial fibrillation, heart failure, and mortality especially in ventricular pacing dependent patients.[1,2] The most physiological pacing strategy, His bundle pacing (HBP), has been demonstrated with reduced risk of heart failure hospitalization and mortality. However, due to higher pacing threshold and lower R-wave amplitude of HBP, the concern of pacing safety limits its application in routine clinical practice.[3–6] Recently, left bundle branch pacing

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What's new?

- Left bundle branch pacing (LBBP) was feasible in bradycardia patients associated with stable pacing parameters during 18 months follow-up.
- The paced QRS duration in LBBP group was significantly narrower than that of right ventricular pacing group.
- The complications and cardiac outcomes were not significantly different between two groups.

(LBBP) is a novel physiological pacing strategy alternative to HBP. Pacing at a more distal and deep area than HBP, it is not difficult to capture left bundle branch (LBB) (left bundle trunk and its proximal fascicles) since LBB is a wide network.[7] Thus, low and stable threshold and high R-wave amplitude of LBBP has been demonstrated during short-term follow-up in several case reports and small-scale observational studies.[8–13] In this study, we prospectively estimate the feasibility and safety of LBBP when compared with RVP during mid-long-term follow-up in a relatively large cohort.

Methods

Study populations

Patients ($n = 554$) indicated for a pacemaker implantation were prospectively and consecutively enrolled from January 2018 to January 2019 and were non-randomized divided into LBBP group and RVP group in terms of patients' selection and clinical practice. Exclusion criteria included: (i) non-specific intraventricular conduction delay; (ii) heart failure with LV ejection fraction <50%; and (iiii) indication for cardiac resynchronization therapy.

Informed consent was obtained from all the patients and the study was approved by the Institutional Review Board of Zhongshan Hospital, Fudan University, Shanghai, China. The baseline characteristics including age, gender, aetiology, and pacemaker type were collected (*Table 1*).

Implantation procedure and intra-procedural characteristics

Left bundle branch pacing was performed following the description in the literatures.[8,12,13] (Supplementary material online, *Figure S1*). Briefly, the pacing lead (Mode 3830 69-cm, Medtronic, Minneapolis, USA) together with the C315 His sheath was attempted to find His bundle location initially in LBBP group through connecting the lead to an electrophysiology (EP) recording system (GE CardioLab EP Recording System 2000 GE Inc., WI, USA). Then the lead was placed ∼1–2 cm distal between the His bundle location and the RV apex under the fluoroscopic image of the right anterior oblique (RAO) 30°. The lead was screwed deeply into the interventricular septum until the paced QRS complex changed from an LBBB to a RBBB morphology. The LBB potential (Po_{LBB}) was recorded and the interval of Po_{LBB} to ventricle (Po_{LBB}-V) was measured (*Figure 1A*). Left bundle branch capture was confirmed by selective LBBP (SLBBP) or the stimulus to left ventricular activation time (Sti-LVAT) shortening abruptly >10 ms by increasing output or remaining shortest and constant at final site. The incidence of SLBBP was recorded and Po_{LBB} to left ventricular activation (Po_{LBB}-LVAT) during intrinsic rhythm and Sti-LVAT during LBBP were measured (*Figures 1–3*). Besides RBBB pattern, paced QRS axis were collected and recorded as normal, left, and right deviations (*Figures 1–3*). The lead depth inside the septum was measured by angiography through contrast injection from the sheath at left anterior oblique (LAO) 35° (*Figures 1D and 3D*). Pre-procedural interventricular septum thickness by echocardiogram was measured and compared with the lead depth above. Right ventricular pacing (RV apex pacing or RV septal pacing) was performed by conventional active fixation lead by the same operators.

cTnT and N-terminal pro-B type natriuretic peptide measurement before and after the procedure

Blood for the evaluation of cTnT and N-terminal pro-B type natriuretic peptide (NT-pro-BNP) was taken from a peripheral vein pre-procedure at baseline, 1 and 2 days post-procedure. The levels of cTnT and NT-pro-BNP were measured and compared in two groups.

Pacing parameters and follow-up

The pacing thresholds, R-wave amplitudes and impedances were measured by unipolar configurations through the programmer (Medtronic 2290) during procedure and follow-up (1, 3, 6, 12, and 18 months post-procedure). QRS duration measured at speed of 100 mm/s during intrinsic rhythm (from the onset to the end of QRS wave) and pacing by unipolar at 3.5 V/0.4 ms (from the stimulus to the end of QRS wave) in two groups were collected. Total fluoroscopy time was documented. The procedure-related complications including lead dislodgement, lead perforation, device or lead infection, pericardial effusion, thromboembolism and ventricular tachycardia, as well as cardiac outcomes including acute coronary artery syndrome, hospitalization of heart failure and cardiovascular mortality were collected and compared in two groups.

Ethical approval

The study was approved by the Institutional Review Board of Zhongshan Hospital, Fudan University, Shanghai, China.

Statistical methods

Continuous variables were reported as means ± standard deviation (SD) and compared by Student's *t*-test. Categorical variables were expressed as percentages and compared by using Pearson's χ^2 test. P values < 0.05 was considered statistically significant. All analyses were done by SPSS version 17 (SPSS Inc., Chicago, IL, USA).

Results

Comparisons of characteristics between left bundle branch pacing and right ventricular pacing group

Left bundle branch pacing was attempted in 250 patients and was successful performed in 237 cases (94.8%). Of 13 cases of LBBP failure, the leads of 5 cases were very easily advanced into the septum and perforated to the left ventricle at multiple different sites (five attempts) when removing the sheath. And the rest eight cases failed due to hard to screw the lead deep enough to achieve a RBBB pattern paced QRS morphology. These 13 cases were received conventional RVP.

At baseline, gender, age, the incidence of hypertension, diabetes and atrial fibrillation, coronary heart disease, valvular heart disease, congenital heart disease, chronic kidney disease, stroke, and pacemaker types were not significantly different in two groups. As

Table 1 Comparisons of characteristics between LBBP and RVP group

	LBBP (*n* = 237)	RVP (*n* = 317)	*P*-Value
Male, *n* (%)	130 (54.85)	157 (49.53)	0.215
Age (years)	67.76 ± 13.29	69.15 ± 11.48	0.631
Hypertension, *n* (%)	102 (43.04)	162 (51.10)	0.060
Diabetes, *n* (%)	35 (14.77)	38 (11.99)	0.338
Atrial fibrillation, *n* (%)	35 (14.77)	31 (9.78)	0.073
Coronary artery disease, *n* (%)	32 (13.50)	46 (14.51)	0.736
Valvular heart disease, *n* (%)	22 (9.28)	20 (6.31)	0.191
Congenital heart disease, *n* (%)	6 (2.53)	3 (0.95)	0.144
Chronic kidney disease, *n* (%)	4 (1.69)	5 (1.58)	0.919
Stroke	16 (6.75)	18 (5.68)	0.626
Pacemaker types			0.069
Single chamber pacemaker, *n* (%)	41 (17.30)	75 (23.66)	
Dual chamber pacemaker, *n* (%)	196 (82.70)	242 (76.34)	
Pacemaker indication			<0.0001
SSS, *n* (%)	75 (31.65)	165 (52.05)	
AVB, *n* (%)	127 (53.58)	121 (38.17)	
Atrial fibrillation with low ventricular rate, *n* (%)	35 (14.77)	31 (9.78)	
Fluoroscopy time (min)	9.15 ± 3.52	3.92 ± 3.76	<0.0001
The number of attempts	2.41 ± 0.78	1.49 ± 0.78	<0.0001
Intrinsic QRS duration (ms)	117.09 ± 25.82	105.04 ± 12.18	<0.0001
Paced QRS duration	122.02 ± 7.93	157.68 ± 15.58	<0.0001
Complications, *n* (%)			0.179
Lead dislodgement	2 (0.8)	6 (1.9)	
Lead perforation	1 (0.4)	0 (0.0)	
Device or lead infection	0 (0.0)	2 (1.0)	
Pericardial effusion	0 (0.0)	0 (0.0)	
Thromboembolism	0 (0.0)	0 (0.0)	
Ventricular tachycardia	1 (0.4)	0 (0.0)	
Cardiac outcomes, *n* (%)			0.673
ACS	1 (0.4)	1 (0.4)	
Hospitalization of heart failure	0 (0.0)	1 (0.4)	
Cardiovascular mortality	0 (0.0)	0 (0.0)	

Compared with baseline.
ACS, acute coronary artery syndrome; AVB, atrioventricular block; LBBP, left bundle branch pacing; RVP, right ventricular pacing; SSS, sick sinus syndrome.
*P < 0.05.
**P < 0.01.
***P < 0.001.

for the pacemaker implantation indication including sick sinus syndrome (SSS), atrioventricular block (AVB), and atrial fibrillation (AF) with low ventricular rate, there was significant difference between two groups (P < 0.0001). The number of attempts and fluoroscopy time between LBBP group and RVP group were significantly different (2.41 ± 0.78 vs. 1.49 ± 0.78, P < 0.0001) (*Table 1*).

Characteristics of left bundle branch pacing during the procedure

Intra-procedural characteristics of patients in LBBP group are summarized in *Table 2*. Po_{LBB} was recorded in 213 patients (89.9%) in total LBBP cases (narrow QRS 208, RBBB 11, and LBBB 18) with a mean Po_{LBB}-V of 21.35 ± 4.89 ms. Po_{LBB} amplitude in LBBP cases were measured as 0.20 ± 0.21 mV. The means of Po_{LBB}-LVAT was 65.32 ± 10.55 ms, which was not significantly different from Sti-LVAT (65.07 ± 8.58 ms) during LBBP. The incidence of SLBBP in LBBP was 57.8%. Normal paced QRS axis (*Figure 1*), left and right axis deviation (*Figures 2 and 3*) accounted for 18.1%, 79.7%, and 2.2% of all LBBP cases, respectively. The means of lead depth inside the septum and interventricular septum thickness measured by echocardiogram were significantly different (12.85 ± 2.20 vs. 9.84 ± 1.56 mm, P < 0.0001). The average fluoroscopy time in LBBP group was 9.15 ± 3.53 min.

cTnT and N-terminal pro-B type natriuretic peptide change post-procedure

Significant difference in the cTnT levels between two groups was noted since baseline (0.03 ± 0.03 vs. 0.02 ± 0.03 ng/mL, P = 0.002) and maintained within 2 days after implantation (1 day: 0.13 ± 0.09 vs.

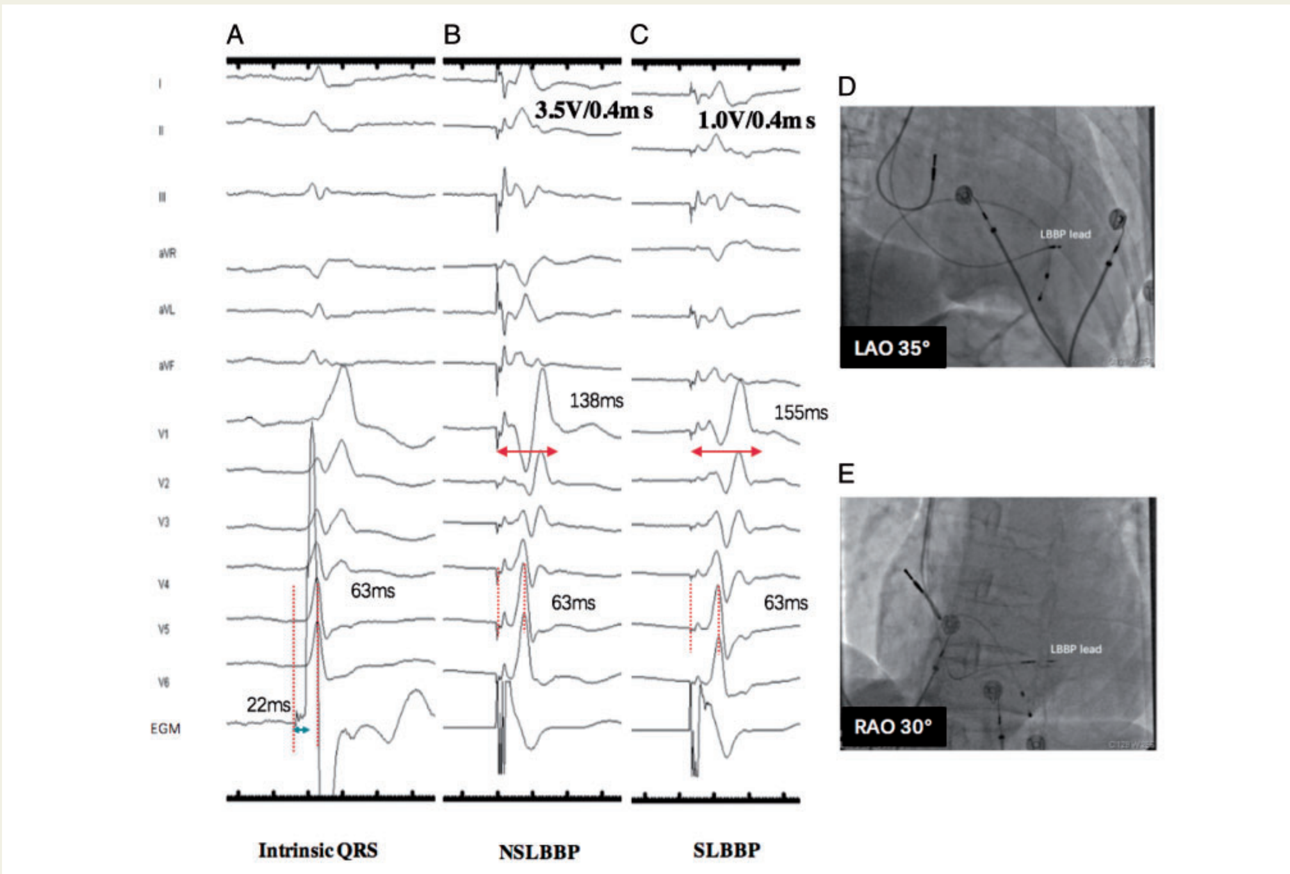

Figure 1 A case of LBBP with paced QRS of normal axis. (*A*) Po_{LBB} during intrinsic rhythm with Po_{LBB}-V interval of 22 ms (blue horizontal arrow) and Po_{LBB}-LVAT was 63 ms (red dotted line); (*B*) non-selective LBBP at 3.5 V/0.4 ms with Sti-LVAT of 63 ms (red dotted line) and QRS duration (from stimulus to the end of QRS) of 138 ms (red horizontal arrow); (*C*) selective LBBP at 1.0 V/04 ms with Sti-LVAT of 63 ms (red dotted line) and QRS duration of 155 ms (red horizontal arrow); (*D*) image at LAO 35°; and (*E*) image at RAO 30°. LBBP, left bundle branch pacing; $Po_{LBB,}$ LBB potential; Po_{LBB}-LVAT, Po_{LBB} to left ventricular activation; Sti-LVAT, stimulus to left ventricular activation time.

0.04 ± 0.03 ng/mL, P < 0.001 and 2 days: 0.10 ± 0.08 vs. 0.03 ± 0.08 ng/mL, P < 0.001) (*Figure 4*). Left bundle branch pacing group had a greater increase in the cTnT levels at 1 and 2 days post-procedure compared with baseline (P < 0.001) while RVP group only depicted a trend (P = 0.557, P = 0.238). N-terminal pro-B type natriuretic peptide values were significantly higher in LBBP group than RVP group at baseline (1097.55 ± 1709.16 vs. 520.73 ± 731.31 pg/mL, P < 0.001) and 1 day after the procedure (1198.60 ± 2162.96 vs. 521.95 ± 753.43 pg/mL, P = 0.002), whereas NT-proBNP at 2 days post-procedure between two groups did not reach statistical difference (P = 0.531) accompanied by a decrease in LBBP patients compared with baseline (P = 0.039).

Pacing parameters during follow-up

QRSd was significantly narrower in LBBP when compared with RVP (132.02 ± 7.93 vs. 177.68 ± 15.58 ms, P < 0.0001) (*Table 1*). The mean follow-up duration was .18.13 ± 1.77 months for LBBP and 18.37 ± 2.13 months for RVP. Generally, the pacing parameters were stable in two groups during follow-up (*Table 3*). The pacing threshold in LBBP group was lower than RVP group at implant (0.59 ± 0.21/0.4 vs. 0.70 ± 0.23 V/0.4 ms, P < 0.0001). Significant differences in R-wave amplitude and impedance between two groups were found since 1 and 6 months follow-up, respectively, which maintained at 18 months follow-up. Higher pacing threshold and decreased impedance could be observed since 1-month follow-up for LBBP group and since 3-month follow-up for RVP group compared with those at implant. Interestingly, sensed R-wave amplitude in LBBP group significantly increased post-procedure and gradually levelled up during the ensuing follow-up while this parameter remained stable in RVP group.

Complications and cardiac outcomes evaluation

Substantially, the incidence of lead complications and cardiac outcomes were not significantly different between two groups (*Table 4*).

In LBBP group, there were two cases of lead dislodgement and one case of lead perforation to the left ventricular cavity during follow-up. In a patient with atrial fibrillation and low ventricular rate receiving a single-chamber pacemaker and a patient with AVB receiving a dual-chamber pacemaker, lead dislodgement confirmed by high threshold, low impedance, and X-ray film were observed at 1 month follow-up. The lead perforation case was SSS receiving a dual-chamber pacemaker with higher threshold

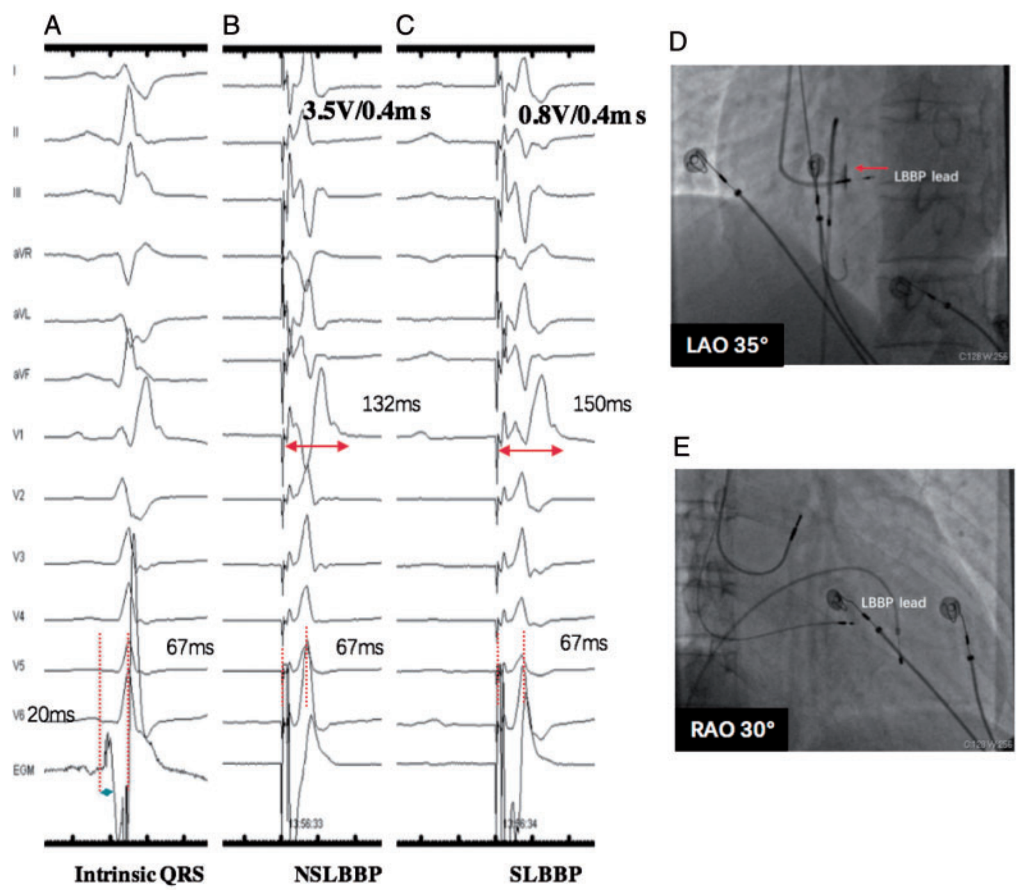

Figure 2 A case of LBBP with paced QRS of left axis deviation. (*A*) Po_{LBB} during intrinsic rhythm with Po_{LBB}-V interval of 20 ms (blue horizontal arrow) and Po_{LBB}-LVAT was 67 ms (red dotted line); (*B*) non-selective LBBP at 3.5 V/0.4 ms with Sti-LVAT of 67 ms (red dotted line) and QRS duration (from stimulus to the end of QRS) of 132 ms (red horizontal arrow); (*C*) selective LBBP at 0.8 V/0.4 ms with Sti-LVAT of 67 ms (red dotted line) and QRS duration of 150 ms (red horizontal arrow); (*D*) image at LAO 35° (the red arrow depicted the lead depth inside the septum measured by angiography through contrast injection from the sheath); and (*E*) image at RAO 30°. LBBP, left bundle branch pacing; $Po_{LBB,}$ LBB potential; Po_{LBB}-LVAT, Po_{LBB} to left ventricular activation; Sti-LVAT, stimulus to left ventricular activation time.

and lower impedance during unipolar pacing than bipolar pacing (5 V/0.4 vs. 2.5 V/0.4 ms and 402 vs. 276 Ω) at 1 month post-procedure. CT scan demonstrated the lead's tip perforation to the left ventricular cavity for ∼10 mm with the ring of lead inside the septum. These three patients were received successful lead reposition to a location away from the initial site. There were no cases of device or lead infections or thromboembolism during follow-up.

There was a case with AVB in LBBP group suffered from left ventricular summit tachycardia (left ventricular outflow-tract tachycardia) 1-month post-procedure and received ablation afterwards. Another patient suffering from ACS 3-month post-procedure was documented and received a stent implantation in both left anterior descending and right coronary artery.

Discussions

The main findings of this relatively large observational study between LBBP and RVP during mid-long-term follow-up are (i) LBBP was feasible with a relatively high success rate of 94.8% in bradycardia patients with high incidence of Po_{LBB} (89.9%), SLBBP (57.8%), and left deviation of paced QRS axis (79.7%); (ii) paced QRS duration was significantly decreased when compared with RVP and the pacing parameters of LBBP remained stable during follow-up; and (ii) though cTnT elevation was more significant in LBBP when compared with RVP within 2 days post-procedure, the complications and cardiac outcomes were not significantly different between two groups.

Left bundle branch pacing is a conduction system pacing innovation in recent years. The feasibility of this technique has been demonstrated in several small-scale and short-term studies. This large observational study also confirmed the feasibility of LBBP with a high success rate. Pacing capture LBB or its proximal fascicles, paced QRS duration was significantly reduced in LBBP when compared with RVP since conduction velocity of conduction system is much faster than that of endomyocardium.[14,15] Left bundle branch pacing is easy to achieve due to the anatomic characteristics of left conduction system as a wide network.[7,16]

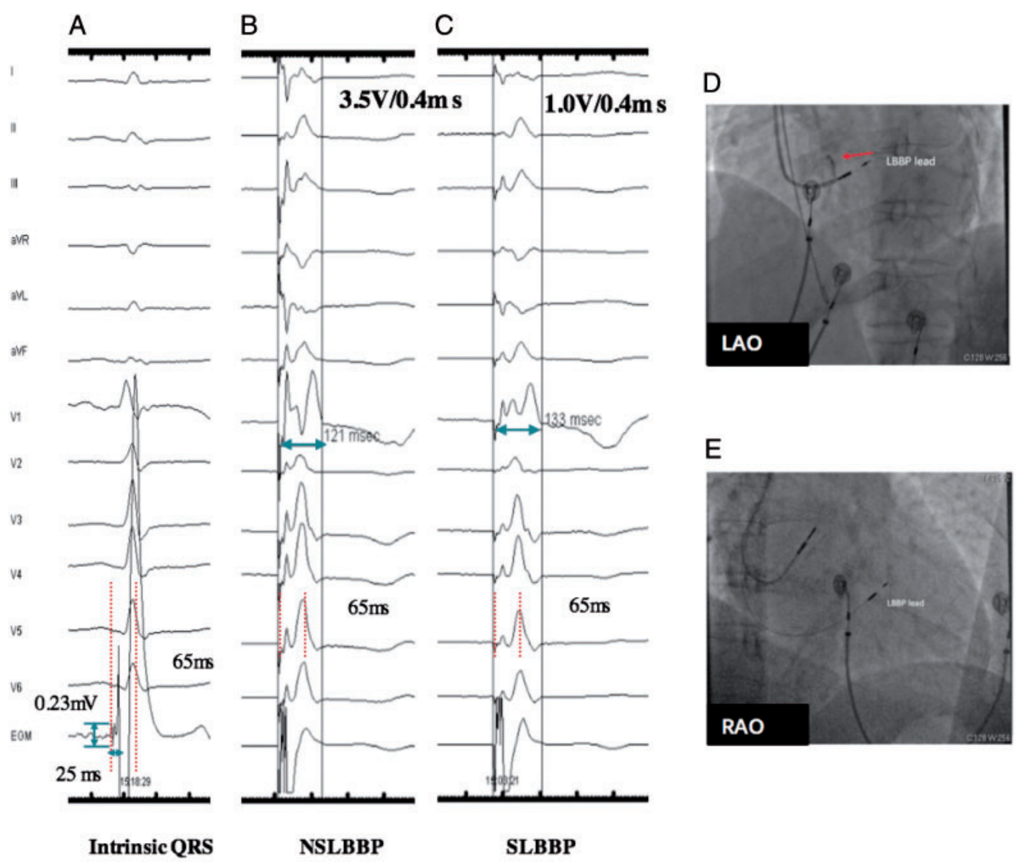

Figure 3 A case of LBBP with paced QRS of right axis deviation. (*A*) Po_{LBB} during intrinsic rhythm with Po_{LBB}-V interval of 25 ms (blue horizontal arrow), Po_{LBB} amplitude of 0.23 mV (blue vertical arrow) and Po_{LBB}-LVAT was 65 ms (red dotted line); (*B*) NSLBBP at 3.5 V/0.4 ms with Sti-LVAT of 65 ms (red dotted line) and QRS duration (from stimulus to the end of QRS) of 121 ms (red horizontal arrow); (*C*) SLBBP at 1.0 V/0.4 ms with Sti-LVAT of 65 ms (red dotted line) and QRS duration of 133 ms (red horizontal arrow); (*D*) image at LAO 35° (the red arrow depicted the lead depth inside the septum measured by angiography through contrast injection from the sheath); and (*E*) image at RAO 35° after the procedure. LBBP, left bundle branch pacing; NSLBBP, non-selective LBBP; SLBBP, selective LBBP; $Po_{LBB,}$ LBB potential; Po_{LBB}-LVAT, Po_{LBB} to left ventricular activation; Sti-LVAT, stimulus to left ventricular activation time.

But the lead needs to be penetrated the muscular ventricular septum to the subendocardium of the left ventricular septum where it comes in contact with the LBB and Purkinje network, as described by our previous animal study.[17] Our data demonstrated the means of lead depth was 12.85 ± 2.20 mm, which was in consistent to the previous study.[12] Since positioning the lead deeply in this region, low pacing threshold and high R-wave amplitude could be achieved similar to RVP. And the pacing parameters remained stable after mid-long-term follow-up due to deep fixation of the lead.

LBB capture could be confirmed by (i) paced QRS of a RBBB pattern, (ii) recording Po_{LBB}, (iii) Sti-LVAT shortens abruptly with increasing output or remains shortest and constant at low and high outputs, and (iv) achieving selective LBBP in clinical practice.[17,18] Our study demonstrated a relatively high incidence of recording Po_{LBB} (89.9%) and achieving SLBBP (57.8%). And the means of Po_{LBB}-LVAT and Sti-LVAT was nearly the same also suggested pacing directly captured LBB. We also found that besides paced QRS of a RBBB pattern in LBBP, QRS axis in most cases was left deviation (79.7%). This was likely due to the anatomic characteristics of a wide left posterior fascicle and a narrow left anterior fascicle as well as the delivery sheath with a fixed septal curve. It was easier to position the lead vertical to the septum with the sheath and screw-in deeply at the posterior septum. While LBB trunk was short and the lead was relatively hard to fix and screw-in since the initial site at the right septum was close to the tricuspid.

The cause of the mild and transient cTnT elevation in the present study was probably related to the procedure itself, which was in accordance with our previous study.[19] All the patients were in apparently good clinical condition and were discharged within 2 days post-procedure without evidence of ACS or pulmonary embolism during peri-procedure. cTnT elevation was found in both two groups while significant increase of cTnT levels was documented in LBBP group at 1 day post-procedure and rapidly decreased at 2 days after implantation. This might probably due to the complexity of the procedure, more times of attempts and

Table 2 Characteristics of LBBP

	LBBP (n = 237)
QRS pattern at baseline	
Narrow QRS (%)	208 (87.76)
RBBB (%)	11 (4.64)
LBBB (%)	18 (7.59)
Po_{LBB} (%)	89.9
Po_{LBB}-V interval (ms)	21.35 ± 4.89
Po_{LBB} amplitude (mV)	0.20 ± 0.21
Po_{LBB}-LVAT (ms)	65.32 ± 10.55[a]
Sti-LVAT (ms)	65.07 ± 8.58[a]
SLBBP (%)	57.8
Paced QRS axis	
Normal (%)	43 (17.30)
Left axis deviation (%)	189 (79.75)
Right axis deviation (%)	5 (2.11)
Lead depth inside septum (mm)	12.85 ± 2.20[b]
Interventricular septum thickness (mm)	9.84 ± 1.56[b]

LBBP, left bundle branch pacing; Po_{LBB}, LBB potential; Po_{LBB}-V, the interval of Po_{LBB} to ventricle; RBBB, right bundle branch block; SLBBP, selective left bundle branch pacing; Sti-LVAT, the stimulus to left ventricular activation time.
[a]Comparisons between Po_{LBB}-LVAT and Sti-LVAT in LBBP, P = 0.895.
[b]Comparisons between lead depth inside septum and interventricular septum thickness in LBBP, P < 0.0001.

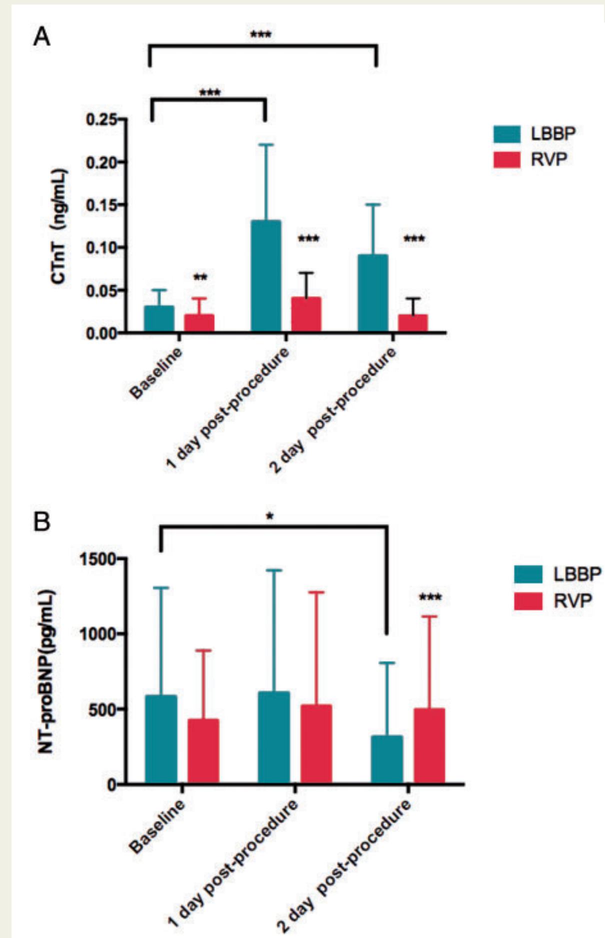

Figure 4 cTnT and NT-proBNP levels at baseline and post-procedure. (*A*) cTnT levels of patients in LBBP and RVP group at baseline, 1 day, and 2 days post-procedure. (*B*) NT-proBNP levels of patients in LBBP and RVP group at baseline, 1 day, and 2 days post-procedure. (*C*) *P < 0.05, **P < 0.01, and ***P < 0.001. LBBP, left bundle branch pacing; NSLBBP, non-selective LBBP; SLBBP, selective LBBP; $Po_{LBB,}$ LBB potential; Po_{LBB}-LVAT, Po_{LBB} to left ventricular activation; Sti-LVAT, stimulus to left ventricular activation time.

deep fixation of the lead, resulting in longer fluoroscopy time and more myocardium injury.

Though significant longer fluoroscopy time and higher cTnT levels post-procedure were documented in LBBP, the complications and cardiac outcomes were not significantly different between two groups, which demonstrated the safety of LBBP during mid-long-term follow-up. Specifically, the number of device infection was even lower in LBBP than RVP in spite of their increased fluoroscopic time. In addition, the lower rate of lead dislodgement, which might result from the deep fixation of the lead inside the septum, indicated another potential advantage of LBBP. However, the efficacy of LBBP to improve the outcome comparing with RVP was not achieved in the present study. This is likely due to the low rate of cardiac events in the study population of normal heart function and relatively short follow-up within 18 months. In light of the relatively longer fluoroscopic time to provide an efficient LBB pacing, the application of intracardiac echo (ICE) could be performed during the procedure to facilitate the screwing process and determine the depth of LBB lead inside the interventricular septum.[20] However, taking into consideration of the increased operation time and hospitalization expenditure, we suggest that ICE might be applied in challenging cases.

Limitations

This is a single-centre, non-randomized observational study. Patients underwent LBBP or RVP on the basis of individual choice and clinical practice of the operators. The lack of randomization led to heterogeneous population which might resulted in bias estimation on the results. Lead performance and the efficacy of LBB capture during long-term follow-up were unknown at present. Long-term, multicentred, and randomized trials are necessary to confirm the feasibility, safety, and benefits of LBBP in bradycardia patients indicated for a pacemaker implantation.

Conclusions

Left bundle branch pacing was feasible with a high success rate in bradycardia patients associated with stable pacing parameters during 18 months follow-up. Paced QRS duration was significantly decreased when compared with RVP. Though cTnT elevation was more significant in LBBP when compared with RVP within 2 days post-procedure, the complications and cardiac outcomes were not significantly different between two groups.

Table 3 Pacing parameters at implant and follow-up

Parameters	LBBP group	*N*	RVP group	*N*	*P*-Value
At implant		237		317	
Pacing threshold (V/0.4 ms)	0.58 ± 0.21		0.71 ± 0.24		<0.0001
R-wave amplitude (mV)	11.82 ± 4.24		11.21 ± 3.32		0.540
Impedance (Ω)	532.61 ± 95.11		520.87 ± 88.43		0.139
1-month follow-up		230		311	
Pacing threshold (V/0.4 ms)	0.63 ± 0.20**		0.72 ± 0.24		0.001
R-wave amplitude (mV)	13.54 ± 5.59**		11.46 ± 3.40		0.003
Impedance (Ω)	530.39 ± 70.16		518.35 ± 79.19		0.040
3-month follow-up		233		312	
Pacing threshold (V/0.4 ms)	0.63 ± 0.20**		0.75 ± 0.24*		<0.0001
R-wave amplitude (mV)	13.21 ± 5.39*		11.36 ± 3.34		0.006
Impedance (Ω)	498.110 ± 63.99***		507.73 ± 68.65		0.389
6-month follow-up		237		315	
Pacing threshold (V/0.4 ms)	0.66 ± 0.20**		0.76 ± 0.23*		<0.0001
R-wave amplitude (mV)	13.33 ± 4.93*		11.17 ± 3.31		0.002
Impedance (Ω)	455.28 ± 64.65***		495.18 ± 62.50**		<0.0001
12-month follow-up		228		310	
Pacing threshold (V/0.4 ms)	0.72 ± 0.23***		0.75 ± 0.24**		0.020
R-wave amplitude (mV)	13.59 ± 5.16**		11.36 ± 3.33		<0.0001
Impedance (Ω)	420.86 ± 66.62***		495.36 ± 61.50***		<0.0001
18-month follow-up		169		226	
Pacing threshold (V/0.4 ms)	0.73 ± 0.25***		0.76 ± 0.24**		0.195
R-wave amplitude (mV)	13.86 ± 5.99***		11.58 ± 3.44		<0.0001
Impedance (Ω)	401.77 ± 66.78***		492.11 ± 58.97***		<0.0001

Compared with implantation.
LBBP, left bundle branch pacing; RVP, right ventricular pacing.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

Supplementary material

Supplementary material is available at *Europace* online.

Conflict of interest: none declared.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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