Yu *et al. International Journal of Arrhythmia* (2023) 24:12
https://doi.org/10.1186/s42444-023-00095-1

International Journal of Arrhythmia

REVIEW **Open Access**

Left bundle branch area pacing with stylet-driven pacing leads: implantation technique

Ga-In Yu[1], Tae-Hoon Kim[2*], Hee Tae Yu[2], Boyoung Joung[2], Hui-Nam Pak[2] and Moon-Hyoung Lee[2]

Abstract

Background Traditional right ventricular apical pacing can cause electrical–mechanical dyssynchrony. Therefore, physiological conduction system pacing was considered and became the reason for developing His bundle pacing (HBP). Recently, left bundle branch area pacing (LBBAP) has been implemented, which overcomes the shortcomings of HBP. Most initial large LBBAP studies reported that LBBAP was achieved through a lumenless pacing lead (LLL) with a fixed helix design; however, it is unavailable in Korea. LBBAP delivery sheaths using a conventional standard stylet-driven pacing lead (SDL) with an extendable helix design are currently available in Korea. In this review, we describe the methods and procedural skills required to perform the LBBAP using conventional SDL.

Main body LBBAP has emerged as a new physiological CSP modality and has shown a stable and lower capture threshold and achieved a similarly paced QRS duration compared to HBP. It has also demonstrated stable early outcomes for feasibility and safety with a high success rate. Furthermore, the application of LBBAP has recently been extended to a resynchronization strategy. The LBBAP with SDL requires different handling and lead preparation owing to differences in lead and helix designs. Reported procedure-related acute complications of LBBAP include septal perforation during the procedure, pneumothorax, pocket infection, pocket hematoma, and lead dislodgements occurring during follow-up.

Conclusion LBBAP with conventional SDL has similar implant success rates, procedural safety, and pacing characteristics as LBBAP with LLL. However, LBBAP with SDL requires different handling and lead preparation from that of LLL owing to the differences in the lead and helix designs.

Keywords Conduction system pacing, Left bundle branch area pacing, Stylet-driven pacing lead

Introduction

Cardiac pacing is an essential therapeutic strategy for bradyarrhythmia. Although cardiac pacing has been performed traditionally at the right ventricular (RV) apex, it causes electrical and mechanical dyssynchrony, which can lead to pacemaker-induced cardiomyopathy and heart failure [1–3]. Consequently, physiological conduction system pacing has emerged, and His bundle pacing (HBP) has been considered the most optimal physiological conduction system pacing (CSP) [4, 5]. However, HBP has some limitations, including difficulty identifying the precise location of the His bundle due to its very small

---

*Correspondence:
Tae-Hoon Kim
thkimcardio@yuhs.ac
[1] Division of Cardiology, Department of Internal Medicine, GyeongSang National University Changwon Hospital, Gyeongsang National University College of Medicine, Changwon, Republic of Korea
[2] Division of Cardiology, Department of Internal Medicine, Severance Hospital, Yonsei University College of Medicine, Seoul, Republic of Korea

area and sometimes high pacing output [6, 7]. Moreover, HBP may not be helpful when the block site is at the infra-Hisian level or in the case of a proximal left bundle branch block (LBBB). Thus, left bundle branch area pacing (LBBAP) that overcomes the shortcomings [7] of HBP has been implemented as an alternative method for physiological CSP [8–11].

LBBAP was achieved early in its revolution using a lumenless pacing lead (LLL) with a fixed helix design, which is unavailable in Korea. However, it is known that LBBAP can be conducted using a conventional standard stylet-driven pacing lead (SDL) with an extendable helix design by utilizing the sheath-guided implantation method [12–14]. Currently, LBBAP is being performed stably in Korea using SDL.

In this review, we describe the methods and detailed procedural skills required for LBBAP implantation using conventional SDL.

Paradigm shift in ventricular pacing

Since the implantable pacemaker was used in humans by C. Walton Lillehei in 1958, artificial pacemakers have become the basis of bradycardia treatment [15]. For approximately 50 years, the standard site for cardiac pacing has been the RV apex. Conventional RV apical pacing reduces symptoms and improves the quality of life, exercise capacity, and survival in patients with sick sinus syndrome and atrioventricular block [16, 17]. However, in some patients, it adversely affects the structure and function of the heart and can cause heart failure (HF) [1–3].

In 2000, Deshmukh et al. introduced permanent HBP to treat bradyarrhythmia [18]. They reported the role of HBP in tachycardia-induced cardiomyopathy in patients with atrial fibrillation. Afterward, meaningful studies on HBP conducted between 2006 and 2011 explained the need for CSP and demonstrated its effectiveness and safety [19–21]. However, these HBPs had some limitations. HBP implantation in an appropriate location is difficult, and the success rate is low, especially in patients with QRS prolongation; even when successful, the pacing capture threshold is often high and requires a high pacing output [6, 7].

Amidst this, LBBAP, proposed by Huang et al. [8], has emerged as a new physiological CSP modality. LBBAP has shown a stable and lower capture threshold and achieved a similarly paced QRS duration compared to HBP [22]. It has also demonstrated stable early outcomes for feasibility and safety with a high success rate [10, 23]. LBBAP has currently become a widely used CSP as stable mid- and long-term outcomes have been reported over the years [9, 24, 25]. Furthermore, the application of LBBAP has recently been extended to a resynchronization strategy (Fig. 1) [26–31].

Definition of left bundle branch pacing (LBBP)

Generally, LBBAP includes deep septal pacing, nonselective LBBP, and selective LBBP. The definitive definition of LBBP is more specific than LBBAP, and we have summarized the definitions of LBBP reported in previous studies.

The success of LBBP is confirmed by observing left bundle branch (LBB) potential directly in the intracardiac electrogram and paced surface 12-lead electrocardiogram (ECG). The generally accepted characteristics of the intracardiac and surface electrocardiograms in LBBP are as follows:

1. LBB potential (LBB-V interval of 15–35 ms).

In patients with non-LBBB during intrinsic rhythm, a sharp high-frequency deflection called LBB potentials is recorded from the pacing lead, with the potential to ventricle interval of 15–35 ms [32–34]. LBB potential to left ventricular activation time (LVAT) interval is equal to the stimulus to LVAT (Stim-LVAT) interval in $V5-V6$ (± 10 ms) [33].

2. Stim-LVAT as measured in $V5-V6 < 75-85$ ms.

Stim-LVAT is defined as the interval from the pacing stimulus to the peak of the R-wave and is often used to reflect the lateral precordial myocardium depolarization time in leads $V5-V6$. Stim-LVAT that shortens abruptly with increasing output or remains the shortest and constant at both low and high outputs suggests LBB capture. Meanwhile, a fast left ventricular (LV) peak activation time of approximately 80 ms is indicative of fast activation propagation throughout the specialized LV conduction fascicules of the LBB [32, 33].

3. QRS morphology transition reflecting LBB pacing during the threshold test [33, 35].

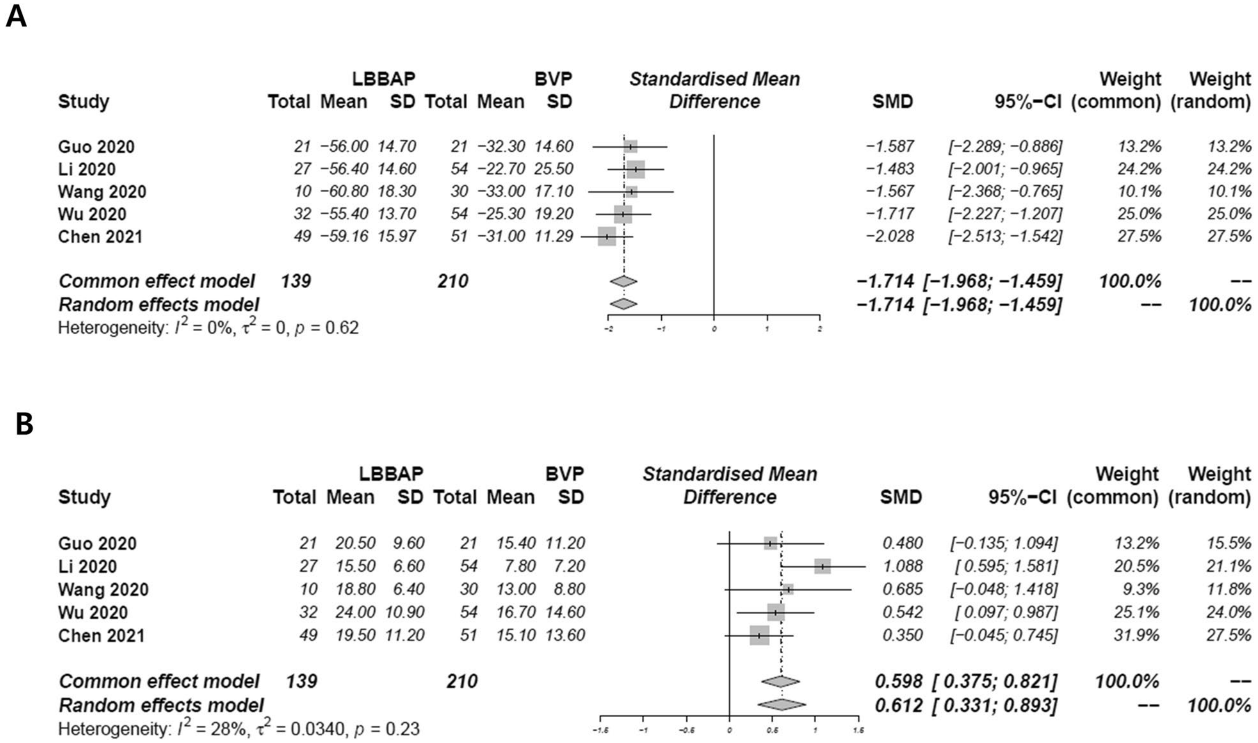
The transition from nonselective LBB capture to selective LBB capture and from nonselective LBB capture to left ventricular septal capture at near-threshold output indicates LBB area pacing.

4. QRS morphology change by the programmed stimulation from pacing lead [33].

Implantation of left bundle branch area pacing

Lumen-less pacing lead versus stylet-driven pacing lead

Most large cases of LBBAP have been exclusively performed using an LLL with a fixed helix design and a preshaped sheath dedicated to this lead [8, 10, 36]. Because



A

Study	LBBAP Total	LBBAP Mean	LBBAP SD	BVP Total	BVP Mean	BVP SD	SMD	95%-CI	Weight (common)	Weight (random)
Guo 2020	21	−56.00	14.70	21	−32.30	14.60	−1.587	[−2.289; −0.886]	13.2%	13.2%
Li 2020	27	−56.40	14.60	54	−22.70	25.50	−1.483	[−2.001; −0.965]	24.2%	24.2%
Wang 2020	10	−60.80	18.30	30	−33.00	17.10	−1.567	[−2.368; −0.765]	10.1%	10.1%
Wu 2020	32	−55.40	13.70	54	−25.30	19.20	−1.717	[−2.227; −1.207]	25.0%	25.0%
Chen 2021	49	−59.16	15.97	51	−31.00	11.29	−2.028	[−2.513; −1.542]	27.5%	27.5%
Common effect model	**139**			**210**			**−1.714**	**[−1.968; −1.459]**	**100.0%**	**--**
Random effects model							**−1.714**	**[−1.968; −1.459]**	**--**	**100.0%**

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.62$

B

Study	LBBAP Total	LBBAP Mean	LBBAP SD	BVP Total	BVP Mean	BVP SD	SMD	95%-CI	Weight (common)	Weight (random)
Guo 2020	21	20.50	9.60	21	15.40	11.20	0.480	[−0.135; 1.094]	13.2%	15.5%
Li 2020	27	15.50	6.60	54	7.80	7.20	1.088	[0.595; 1.581]	20.5%	21.1%
Wang 2020	10	18.80	6.40	30	13.00	8.80	0.685	[−0.048; 1.418]	9.3%	11.8%
Wu 2020	32	24.00	10.90	54	16.70	14.60	0.542	[0.097; 0.987]	25.1%	24.0%
Chen 2021	49	19.50	11.20	51	15.10	13.60	0.350	[−0.045; 0.745]	31.9%	27.5%
Common effect model	**139**			**210**			**0.598**	**[0.375; 0.821]**	**100.0%**	**--**
Random effects model							**0.612**	**[0.331; 0.893]**	**--**	**100.0%**

Heterogeneity: $I^2 = 28\%$, $\tau^2 = 0.0340$, $p = 0.23$

Fig. 1 Outcome of LBBAP. Reduction in the QRS duration (**A**). Improvement in left ventricular ejection fraction (**B**). *LBBAP* Left bundle branch area pacing; *BVP* biventricular pacing, *SD* standard deviation, *SMD* standard mean difference, *CI* confidence interval

the LLL has no inner lumen, the lead body diameter is relatively as small as 4.1 Fr and is an isodiametric lead with a fixed helix (1.8 mm length) design. LLL does not have a stylet; therefore, a dedicated delivery sheath is required. There are two types of sheath: fixed double curve (C315 His, Medtronic Inc., Minneapolis, USA) and deflectable curve (C304 and C304 His, Medtronic Inc., Minneapolis, USA). Meanwhile, the only commercially available LLL is the Select Secure 3830 pacing lead (Medtronic Inc., Minneapolis, USA).

Moreover, it has been reported that LBBAP using a standard stylet-driven lead is available [12–14]. Because SDL has an inner lumen for stylet insertion, the lead body diameter is larger than that of LLL with > 5.5 Fr. The helix has an extendable–retractable design (1.8–2.0 mm fully extended length). Because the SDL has a larger diameter than the LLL, the electrically active helical surface has a larger SDL. Commercialized SDLs include Solia S pacing lead (Biotronik, SE & Co., Berlin, Germany), Ingevity pacing lead (Boston Scientific Inc., Marlborough, USA), and Tendril 2088TC pacing lead (Abbott, Inc., Chicago Illinois, USA). Additionally, the SDL is delivered through a sheath because it properly targets the pacing site and maintains sufficient backup during lead implantation. Sheaths approved for SDL implantation are Selectra 3D pre-shaped sheath (Biotronik, SE & Co., Berlin, Germany), SSPC pre-shaped sheath (Boston Scientific Inc., Marlborough, USA), and Agilis HisPro deflectable sheath (Abbott, Inc., Chicago, Illinois, USA). The sheath size is 7–9 F and has a side port; hence, the contrast medium can be used if necessary.

Lead preparation of SDL

The LBBAP with SDL requires different handling and lead preparation owing to differences in lead and helix designs. Here, we describe a procedure using the SDL with Solia S pacing lead. The lead preparation was performed as previously described [12–14]. The Solia S pacing lead (Biotronik, SE & Co., Berlin, Germany) is a 5.6-Fr-sized SDL with an extendable helix design. The lead body comprises inner and outer coils, and the distal of the inner coil is connected to the helix and proximal to the rotating pin of the pacing lead. When positioning is attempted with the helix out, the lead hangs better, and the parameters are more accurate during pace mapping, thus extending the helix before positioning the lead in the LBBAP area. The lead body is prepared by exposing the extendable screw by turning the outer pin 10–12 times clockwise (Fig. 2A), followed by an additional turning of the outer pin five times clockwise using the standard stylet guide tool delivered with the lead to avoid partial unwinding of the extendable helix (Fig. 2B). The helix

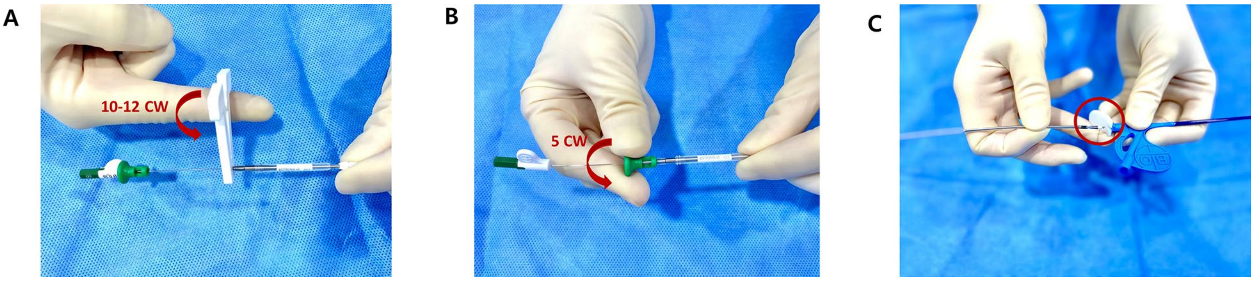


Fig. 2 Lead preparation for LBBAP with SDL. The helix is extended by turning the outer pin 10–12 times clockwise (**A**). The partial unwinding of the extendable helix was avoided by the additional turning of the outer pin of the helix 5 times clockwise (**B**). The lead is placed in the sheath using a transvalvular insertion tool (**C**). *LBBAP* Left bundle branch area pacing, *SDL* stylet-driven pacing lead, *CW* clockwise

may be extended before the lead is placed in the sheath or after the lead is placed in the sheath; however, in the former case, the extended helix may be damaged by the check-valve of the sheath. Therefore, it is recommended to use a transvalvular insertion tool when inserting the lead into the sheath (Fig. 2C).

In the case of the sheaths produced by the companies Biotronik SE & Co. and Boston Scientific Inc., since there are sheaths that are the pre-shaped type and a fixed form, the selection of the sheath before the procedure can affect the result of the procedure outcome. The Biotronik SE & Co. sheath has three types of lengths and three different sizes of curves, and one of a total of nine types of the sheath was selected in a previous study. The initial choice was to select a mid-length, mid-size curve (Selectra 3D-55-39) that was more suitable for the size of the heart. Consequently, the sheath used changes to a smaller or larger size depending on the size of the patient's heart. For the Boston Scientific Inc. sheath, one of the four types of sheaths with the same length and different curve shapes was selected in a previous study. The initial attempt was to use a sheath with a general curve (SSPC2), which could be changed to a more C-shaped or an extended hook depending on the shape of the heart.

Finding the sweet spot for LBBP

To determine the initial screwing position, the methods of exploring the LBB area based on His area and determining the position using the nine-partition method are generally used [35, 37]. The method based on His area is as follows: After confirming His area with a catheter, place the lead tip at 1–2 cm toward the RV apex from His area in the right anterior oblique (RAO) view and perpendicular to the septum in the left anterior oblique (LAO) view, as described in previous studies [35, 38]. Particularly, by positioning a His/RV catheter in the RV and His area, His potential mapping as a landmark and ventricular backup pacing are possible. Although this method has been reported to have a high success rate, it cannot be applied to patients without signs. The nine-partition fluoroscopic method would be useful if His potential is not visible [39]. In this method, an RAO fluoroscopic image of the ventricle is divided into nine sections and two specific partitions (high and median septum middle areas) as LBB areas, and the leads were placed by targeting these areas. This method may take longer because the target site is wider than that of the method using the area as a landmark; however, this method is also reported to have a high success rate [39, 40].

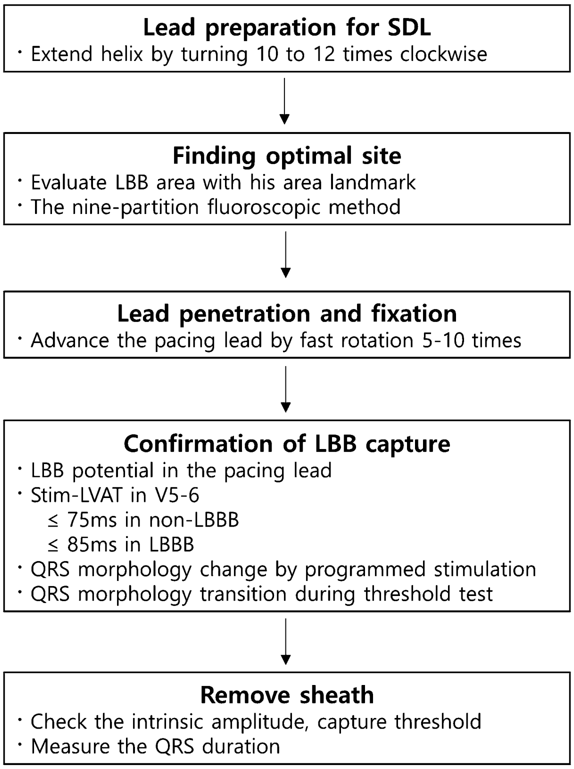


Fig. 3 Flowchart of steps of LBBAP. *LBBAP* Left bundle branch area pacing, *SDL* stylet-driven pacing lead, *LBB* left bundle branch, *Stim-LVAT* stimulus to left ventricular activation time

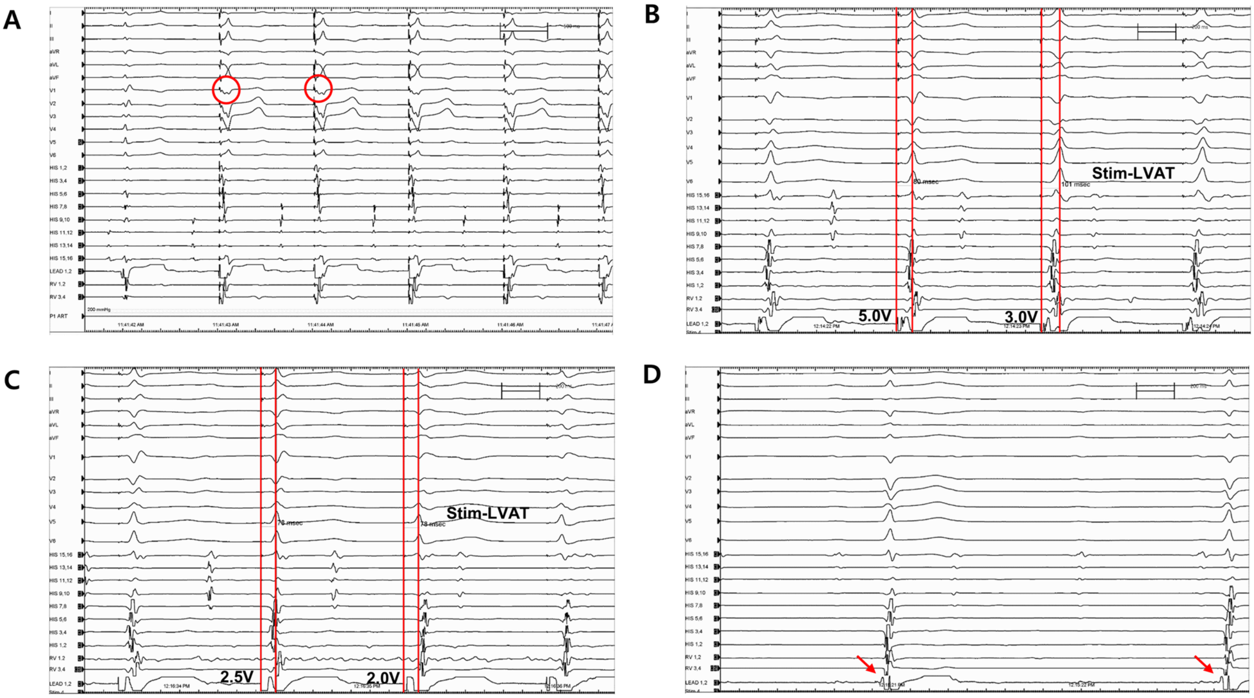


Fig. 4 Examples of intracardiac electrograms during the LBBAP. After initial penetration with 10 rapid rotations of the whole lead body, unipolar pacing showed the LBBB in V1 (**A**, red round). High-output pacing (3–5 V) shows nonselective capture, and lower-output pacing (2.5 V) reveals a transition from nonselective capture to LV myocardial capture (**B**). After further advancement of the lead tip by one or two rotations, a transition from nonselective LBB capture (at 2.5 V) to selective LBB capture (at 2.0 V) is observed (**C**). The LBB potential is also shown (**D**, red arrow). *LBBAP* Left bundle branch area pacing, *LBB* left bundle branch, *Stim-LVAT* stimulus to left ventricular activation time

Lead penetration and fixation

To maintain lead tension, screw the pacing lead interventricular septum from the right side to the left side while ensuring the stylet is inserted fully. Subsequently, advance the pacing lead by fast rotation 5–10 times to overcome the septal resistance, and keep the stylet in pacing lead until the final position is reached [13]. Sudden decrease in lead impedance, sensed R-wave amplitude, and/or loss of capture indicates that the helix of the lead has entered the chamber of the left ventricle, for example, LV perforation; if this occurs, the pacing lead should be rotated back and relocated.

Confirmation of LBB capture

Pacing the right side of the IVS produces an ECG QRS configuration with an LBBB pattern. With the advancement of the lead, the LBBB pattern gradually diminishes until an ECG QRS configuration with an RBBB configuration in lead V1 is observed, suggesting the site of pacing at the LBB. At this point, during programmed stimulation, a fast peak LV activation time in leads *V*5–*V*6 of approximately 75–80 ms should be noted, which demonstrates the transition from deep ventricular septal pacing to LBBAP. When the pacing lead is near or at the LBB, an LBB potential can be recorded [37, 41]. After confirming the LBBP, remove the sheath using a slitter with the stylet pulled back slightly. Following the completion of the procedure, bipolar pacing parameters should be tested because the local ventricular EGM for distinguishing between selective and nonselective LBBP may be unclear on the unipolar paced lead. The above procedure steps are summarized in Fig. 3, and examples of intracardiac electrograms during LBBAP are summarized in Fig. 4.

Avoid complications

Reported procedure-related acute complications of LBBAP include septal perforation during the procedure, pneumothorax, pocket infection, pocket hematoma, and lead dislodgements occurring during follow-up [42, 43]. Particularly, attention should be paid to the septal perforation occurrence in the case of the LBBAP procedure, unlike in the case of other cardiac implantable electronic devices. Generally, a method of continuously checking the drop (<500 ohms) of lead impedance is used to detect septal perforation [35, 41], and recently, it has been reported that the unipolar pacing parameters (unipolar electrograms of <450 ohms) and electrograms (unfiltered unipolar electrograms of QS or RS/rS) have high specificity and sensitivity to identify septal perforation in patients who undergoing LBBAP [44]. This monitoring process not only affects the acute success rate of the procedures but is also a way to avoid long-term unfavorable outcomes.

Conclusions

LBBAP with conventional SDL has similar implant success rates, procedural safety, and pacing characteristics as LBBAP with LLL. Owing to the differences in the lead and helix designs, LBBAP with SDL requires different handling and lead preparation from LLL. However, the method of exploring the target site and confirming the LBBP was not significantly different from the procedure using LLL.

Abbreviations

CSP	Conduction system pacing
ECG	Electrocardiogram
HBP	His bundle pacing
HF	Heart failure
LAO	Left anterior oblique
LBB	Left bundle branch
LBBAP	Left bundle branch area pacing
LBBB	Left bundle branch block
LLL	Lumen-less pacing lead
LV	Left ventricular
LVAT	Left ventricular activation time
RAO	Right anterior oblique
RV	Right ventricular
Stim-LVAT	Stimulus to left ventricular activation time
SDL	Stylet-driven pacing lead

Acknowledgements

Not applicable.

Author contributions

GY and TK summarized the procedure and wrote the manuscript; GY and HY reviewed the articles and performed data analyses; BJ, HP, and ML reviewed the literature; and all authors reviewed the manuscript.

Funding

Not applicable.

Availability of data and materials

The data underlying this article will be shared upon reasonable request from the corresponding authors.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Not applicable.

Received: 2 February 2023 Accepted: 9 May 2023

References

1. Sweeney MO, Hellkamp AS, Ellenbogen KA, et al. Adverse effect of ventricular pacing on heart failure and atrial fibrillation among patients with normal baseline QRS duration in a clinical trial of pacemaker therapy for sinus node dysfunction. Circulation. 2003;107:2932–7. https://doi.org/10.1161/01.CIR.0000072769.17295.B1.
2. Khurshid S, Epstein AE, Verdino RJ, et al. Incidence and predictors of right ventricular pacing-induced cardiomyopathy. Heart Rhythm. 2014;11:1619–25. https://doi.org/10.1016/j.hrthm.2014.05.040.
3. Cicchitti V, Radico F, Bianco F, et al. Heart failure due to right ventricular apical pacing: the importance of flow patterns. Europace. 2016;18:1679–88. https://doi.org/10.1093/europace/euw024.
4. Vijayaraman P, Chung MK, Dandamudi G, et al. His bundle pacing. J Am Coll Cardiol. 2018;72:927–47. https://doi.org/10.1016/j.jacc.2018.06.017.
5. Zanon F, Ellenbogen KA, Dandamudi G, et al. Permanent His-bundle pacing: a systematic literature review and meta-analysis. Europace. 2018;20:1819–26. https://doi.org/10.1093/europace/euy058.
6. Lustgarten DL, Crespo EM, Arkhipova-Jenkins I, et al. His-bundle pacing versus biventricular pacing in cardiac resynchronization therapy patients: a crossover design comparison. Heart Rhythm. 2015;12:1548–57. https://doi.org/10.1016/j.hrthm.2015.03.048.
7. Sharma PS, Dandamudi G, Herweg B, et al. Permanent His-bundle pacing as an alternative to biventricular pacing for cardiac resynchronization therapy: a multicenter experience. Heart Rhythm. 2018;15:413–20. https://doi.org/10.1016/j.hrthm.2017.10.014.
8. Huang W, Su L, Wu S, et al. A novel pacing strategy with low and stable output: pacing the left bundle branch immediately beyond the conduction block. Can J Cardiol. 2017;33:1736e1731–3. https://doi.org/10.1016/j.cjca.2017.09.013.
9. Chen X, Jin Q, Bai J, et al. The feasibility and safety of left bundle branch pacing versus right ventricular pacing after mid-long-term follow-up: a single-centre experience. Europace. 2020;22:ii36–44. https://doi.org/10.1093/europace/euaa294.
10. Li X, Li H, Ma W, et al. Permanent left bundle branch area pacing for atrioventricular block: feasibility, safety, and acute effect. Heart Rhythm. 2019;16:1766–73. https://doi.org/10.1016/j.hrthm.2019.04.043.
11. Chen KP, Li YQ, Dai Y, et al. Comparison of electrocardiogram characteristics and pacing parameters between left bundle branch pacing and right ventricular pacing in patients receiving pacemaker therapy. Europace. 2019;21:673–80. https://doi.org/10.1093/europace/euy252.
12. Zanon F, Marcantoni L, Pastore G, Baracca E. Left bundle branch pacing by standard stylet-driven lead: preliminary experience of two case reports. HeartRhythm Case Rep. 2020;6:614–7. https://doi.org/10.1016/j.hrcr.2020.06.005.
13. De Pooter J, Calle S, Timmermans F, Van Heuverswyn F. Left bundle branch area pacing using stylet-driven pacing leads with a new delivery sheath: a comparison with lumen-less leads. J Cardiovasc Electrophysiol. 2021;32:439–48. https://doi.org/10.1111/jce.14851.
14. Gillis K, O'Neill L, Wielandts JY, et al. Left bundle branch area pacing guided by continuous uninterrupted monitoring of unipolar pacing characteristics. J Cardiovasc Electrophysiol. 2022;33:299–307. https://doi.org/10.1111/jce.15302.
15. Steinhaus D. Fifty years of pacemaker advancements. J Cardiovasc Transl Res. 2008;1:252–3. https://doi.org/10.1007/s12265-008-9076-3.
16. Lamas GA, Pashos CL, Normand SL, McNeil B. Permanent pacemaker selection and subsequent survival in elderly medicare pacemaker recipients. Circulation. 1995;91:1063–9. https://doi.org/10.1161/01.cir.91.4.1063.
17. Sweeney MO, Bank AJ, Nsah E, et al. Minimizing ventricular pacing to reduce atrial fibrillation in sinus-node disease. N Engl J Med. 2007;357:1000–8. https://doi.org/10.1056/NEJMoa071880.
18. Deshmukh P, Casavant DA, Romanyshyn M, Anderson K. Permanent, direct His-bundle pacing: a novel approach to cardiac pacing in patients with normal His-Purkinje activation. Circulation. 2000;101:869–77. https://doi.org/10.1161/01.cir.101.8.869.
19. Occhetta E, Bortnik M, Marino P. Permanent parahisian pacing. Indian Pacing Electrophysiol J. 2007;7:110–25.
20. Kronborg MB, Mortensen PT, Gerdes JC, Jensen HK, Nielsen JC. His and para-His pacing in AV block: feasibility and electrocardiographic findings. J Interv Card Electrophysiol. 2011;31:255–62. https://doi.org/10.1007/s10840-011-9565-1.
21. Catanzariti D, Maines M, Manica A, et al. Permanent His-bundle pacing maintains long-term ventricular synchrony and left ventricular

performance, unlike conventional right ventricular apical pacing. Europace. 2013;15:546–53. https://doi.org/10.1093/europace/eus313.
22. Hua W, Fan X, Li X, et al. Comparison of left bundle branch and his bundle pacing in bradycardia patients. JACC Clin Electrophysiol. 2020;6:1291–9. https://doi.org/10.1016/j.jacep.2020.05.008.
23. Padala SK, Master VM, Terricabras M, et al. Initial experience, safety, and feasibility of left bundle branch area pacing: a multicenter prospective study. JACC Clin Electrophysiol. 2020;6:1773–82. https://doi.org/10.1016/j.jacep.2020.07.004.
24. Zhu H, Wang Z, Li X, et al. Medium- and long-term lead stability and echocardiographic outcomes of left bundle branch area pacing compared to right ventricular pacing. J Cardiovasc Dev Dis. 2021. https://doi.org/10.3390/jcdd8120168.
25. Su L, Wang S, Wu S, et al. Long-term safety and feasibility of left bundle branch pacing in a large single-center study. Circ Arrhythm Electrophysiol. 2021;14:e009261. https://doi.org/10.1161/CIRCEP.120.009261.
26. Guo J, Li L, Xiao G, et al. Remarkable response to cardiac resynchronization therapy via left bundle branch pacing in patients with true left bundle branch block. Clin Cardiol. 2020;43:1460–8. https://doi.org/10.1002/clc.23462.
27. Li X, Qiu C, Xie R, et al. Left bundle branch area pacing delivery of cardiac resynchronization therapy and comparison with biventricular pacing. ESC Heart Fail. 2020;7:1711–22. https://doi.org/10.1002/ehf2.12731.
28. Wang Y, Gu K, Qian Z, et al. The efficacy of left bundle branch area pacing compared with biventricular pacing in patients with heart failure: a matched case-control study. J Cardiovasc Electrophysiol. 2020;31:2068–77. https://doi.org/10.1111/jce.14628.
29. Chen X, Ye Y, Wang Z, et al. Cardiac resynchronization therapy via left bundle branch pacing versus optimized biventricular pacing with adaptive algorithm in heart failure with left bundle branch block: a prospective, multi-centre, observational study. Europace. 2022;24:807–16. https://doi.org/10.1093/europace/euab249.
30. Wu S, Su L, Vijayaraman P, et al. Left bundle branch pacing for cardiac resynchronization therapy: nonrandomized on-treatment comparison with his bundle pacing and biventricular pacing. Can J Cardiol. 2021;37:319–28. https://doi.org/10.1016/j.cjca.2020.04.037.
31. Burri H, Jastrzebski M, Cano O, et al. EHRA clinical consensus statement on conduction system pacing implantation: endorsed by the Asia Pacific Heart Rhythm Society (APHRS), Canadian Heart Rhythm Society (CHRS), and Latin American Heart Rhythm Society (LAHRS). Europace. 2023;25:1208–36. https://doi.org/10.1093/europace/euad043.
32. Chen X, Wu S, Su L, Su Y, Huang W. The characteristics of the electrocardiogram and the intracardiac electrogram in left bundle branch pacing. J Cardiovasc Electrophysiol. 2019;30:1096–101. https://doi.org/10.1111/jce.13956.
33. Jastrzebski M, Kielbasa G, Curila K, et al. Physiology-based electrocardiographic criteria for left bundle branch capture. Heart Rhythm. 2021;18:935–43. https://doi.org/10.1016/j.hrthm.2021.02.021.
34. Wu S, Chen X, Wang S, et al. Evaluation of the criteria to distinguish left bundle branch pacing from left ventricular septal pacing. JACC Clin Electrophysiol. 2021;7:1166–77. https://doi.org/10.1016/j.jacep.2021.02.018.
35. Huang W, Chen X, Su L, et al. A beginner's guide to permanent left bundle branch pacing. Heart Rhythm. 2019;16:1791–6. https://doi.org/10.1016/j.hrthm.2019.06.016.
36. Vijayaraman P, Subzposh FA, Naperkowski A, et al. Prospective evaluation of feasibility and electrophysiologic and echocardiographic characteristics of left bundle branch area pacing. Heart Rhythm. 2019;16:1774–82. https://doi.org/10.1016/j.hrthm.2019.05.011.
37. Zhang S, Zhou X, Gold MR. Left bundle branch pacing: JACC review topic of the week. J Am Coll Cardiol. 2019;74:3039–49. https://doi.org/10.1016/j.jacc.2019.10.039.
38. Chen KP, Li YQ. How to implant left bundle branch pacing lead in routine clinical practice. J Cardiovasc Electrophysiol. 2019;30:2569–77. https://doi.org/10.1111/jce.14190.
39. Jiang H, Hou X, Qian Z, et al. A novel 9-partition method using fluoroscopic images for guiding left bundle branch pacing. Heart Rhythm. 2020;17:1759–67. https://doi.org/10.1016/j.hrthm.2020.05.018.
40. Zhang J, Wang Z, Zu L, et al. Simplifying physiological left bundle branch area pacing using a new nine-partition method. Can J Cardiol. 2021;37:329–38. https://doi.org/10.1016/j.cjca.2020.05.011.
41. Ponnusamy SS, Arora V, Namboodiri N, et al. Left bundle branch pacing: a comprehensive review. J Cardiovasc Electrophysiol. 2020;31:2462–73. https://doi.org/10.1111/jce.14681.
42. Li X, Fan X, Li H, et al. ECG patterns of successful permanent left bundle branch area pacing in bradycardia patients with typical bundle branch block. Pacing Clin Electrophysiol. 2020;43:781–90. https://doi.org/10.1111/pace.13982.
43. Vijayaraman P, Ponnusamy S, Cano O, et al. Left bundle branch area pacing for cardiac resynchronization therapy: results from the international LBBAP collaborative study group. JACC Clin Electrophysiol. 2021;7:135–47. https://doi.org/10.1016/j.jacep.2020.08.015.
44. Ponnusamy SS, Basil W, Vijayaraman P. Electrophysiological characteristics of septal perforation during left bundle branch pacing. Heart Rhythm. 2022;19:728–34. https://doi.org/10.1016/j.hrthm.2022.01.018.

Publisher's Note