Received: 20 June 2023 | Revised: 4 September 2023 | Accepted: 24 September 2023

DOI: 10.1111/pace.14836

PACE WILEY

DEVICES

Outcomes of left bundle branch area pacing compared to His bundle pacing as a primary pacing strategy: Systematic review and meta-analysis

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[Correction added on March 28, 2024, after first online publication: Projekt DEAL funding statement has been added.]

Abstract

Background: Novel pacing technologies, such as His bundle pacing (HBP) and left bundle branch area pacing (LBBaP), have emerged to maintain physiological ventricular activation. We investigated the outcomes of LBBP with HBP for patients requiring a de novo permanent pacing.

Methods and Results: Systematic review of randomized clinical trials and observational studies comparing LBBaP with HBP until March 01, 2023 was performed. Random and fixed effects meta-analyses of the effect of pacing technology on outcomes were performed. Study outcomes included pacing metrics, QRS duration, lead revision, procedure parameters, all-cause mortality and heart failure hospitalization (HFH). Overall, 10 studies with 1596 patients were included. Implant success rate was higher in LBBaP compared with HBP (RR 1.24, 95% CI: 1.08 to 1.42, $p = .002$). LBBaP was associated with lower capture threshold at implantation (mean difference (MD) −0.62 V, 95% CI: −0.74 to −0.51 V, $p < .0001$) and at follow-up (MD −0.74 V, 95% CI: −0.96 to −0.53, $p < .0001$), shorter procedure duration (MD −14.66 min, 95% CI: −23.54 to −5.78, $p = .001$) and shorter fluoroscopy time (MD −4.2 min, 95% CI: −8.4 to −0.0, $p = .05$). Compared with HBP, LBBaP was associated with a decreased risk of all-cause mortality (RR: 0.50, 95% CI: 0.33 to 0.77, $p = .002$) and HFH (RR: 0.57, 95% CI: 0.33 to 1.00, $p = .05$). No statistical differences were found in lead revisions and QRS duration before and after pacing.

Conclusion: This meta-analysis found that LBBaP was superior to HBP regarding pacing metrics and implant success rate as an initial pacing strategy, although absence

Abbreviations: AF, atrial fibrillation; AV, atrioventricular; CI, confidence interval; HBP, His bundle pacing; HF, heart failure; HFH, heart failure hospitalization; HFmrEF, heart failure with mildly reduced ejection fraction; LBBaP, left bundle brunch area pacing; LV, left ventricle ejection fraction; RCT, randomized controlled trials; RR, risk ratio; RVP, right ventricular pacing; SD, standard deviation.

of head-to-head randomized comparison warrants caution in interpretation of the results.

KEYWORDS
cardiac pacing, clinical outcomes, His-bundle pacing, left bundle branch pacing, meta-analysis, systematic review

1 | INTRODUCTION

Permanent right ventricular pacing (RVP) is recommended by current international guidelines to treat bradyarrhythmia as it is associated with improved clinical outcomes.[1,2] However, chronic RVP may cause electrical and mechanical dyssynchrony leading to left ventricular (LV) dysfunction, tricuspid valve regurgitation and an increased risk of atrial fibrillation (AF).[3–6]

Novel pacing technologies, such as His bundle pacing (HBP) and left bundle branch area pacing (LBBaP), have emerged to maintain physiological ventricular activation via the native His-Purkinje system.[1,4] Recent studies and meta-analyses have shown that HBP is superior in preserving electrical synchrony and LV ejection function (LVEF) compared with RVP.[4,6,7] However, it was associated with a higher complication rate, including lead revision, increase in pacing threshold over time, and longer procedure duration.[4,7] Recently, LBBaP was developed as an alternative to HBP to preserve LV function and correct left bundle branch block (LBBB) with a lower complication rate.[8,9]

Still, there is limited information concerning the comparative effectiveness of these novel pacing strategies[1,2] and thus the optimal pacing method for this group of patients remains uncertain. Notably, the 2021 guidelines of the European Society of Cardiology for pacing recommend HBP (class IIb recommendation) as an initial pacing strategy in patients with atrioventricular block (AVB) and heart failure (HF) with mildly reduced ejection fraction (HFmrEF) in whom a high proportion of ventricular pacing is expected.[1] Recommendations for the use of LBBaP could not be given in the current guidelines due to scarce data. Therefore, we aimed to compare HBP with LBBaP as an initial pacing strategy for unselected groups of requiring de novo permanent pacemaker implantation.

2 | METHODS

2.1 | Systematic review

2.1.1 | Search strategy

We conducted a systematic review of the published randomized controlled trials (RCTs) and controlled observational studies in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement (10), using MEDLINE and Embase via OVID®. The initial search strategy was developed in MEDLINE using keywords and Medical Subject Headings (MeSH) terms (Table S1), and the final strategies were then developed using an iterative process incorporating findings from citations and grey literature search. We included the main publications of major studies from which our search obtained only sub-studies. The search was restricted to full-text articles published in English between January 01, 2013 and February 25, 2023.

2.2 | Study selection

We included studies that: (1) compared directly the effects of HBP versus LBBaP, (2) evaluated adults (≥18 years of age) with an indication for permanent pacing, (3) reported at least one outcome of interest for comparison at implantation and at any point during the follow-up period, and (4) provided data that allowed the comparison between the study arms (i.e., means and standard deviations [SD] or medians and interquartile ranges [IQR]). When data by the same authors or the same institution in an overlapping period were identified, only the most recent results were considered. Only English-language studies were included. A reference manager software (Zotero) was used for duplicates removal and data management. Two reviewers (AA and NS) independently reviewed the abstracts of the identified articles against the predefined inclusion criteria. Disagreements were solved with discussion. Due to the small number of included trials (<10) for each comparison group, exploration of any potential publication bias was not performed"

2.3 | Data extraction

For the selected studies, two investigators (AA and NS) reviewed the full texts and used the same template to extract data relevant to the analysis on an Excel spreadsheet. The study design, as well as the sample size, duration of follow-up and primary endpoints were extracted as shown in Table 1.

2.4 | Statistical analysis

The primary outcomes for the study were pacing metrics. The secondary outcomes were QRS duration, lead revision, procedure parameters, all-cause mortality and HF hospitalization (HFH). To compare outcomes between studies investigating HBP versus LBBaP, we pooled the available data (number of events for dichotomous

TABLE 1 Baseline characteristics of studies comparing, HBP and LBBaP as a primary pacing strategy for patients required permanent pacemaker.

Study	Study design	FU (months)	Pacing mode	Number of participants	Indication for pacing	Primary endpoint	Baseline EF (%)	Pacing burden %
Hou et al. 2019[11]	Observational crossover	6	HPB vs. LBBaP	29 vs. 56	AV block or SND	LV dyssynchrony	63.3 ± 5.8 vs.63.8 ± 3.2	NA
Qian et al. 2020[12]	Retrospective	12	HPB vs. LBBaP	64 vs. 185	Bradycardia, HF, AF with AVN ablation	ECG and pacing metrics	47 ± 5.4 vs. 48.3 ± 6.6	NA
Hua et al. 2020[13]	Retrospective	3	HPB vs. LBBaP	125 vs. 126	AV block or SND	ECG and pacing metrics	57.4 ± 8.2 vs. 58.7 ± 7.2	NA
Vijayaraman et al. 2020[14]	Retrospective	12	HPB vs. LBBaP	46 vs. 28	Pacing indication after TAVI	Pacing metrics	57 ± 12 vs. 59 ± 12	NA
Sheng et al. 2021[16]	Retrospective	3	HPB vs. LBBaP	26 (crossover)	Symptomatic bradycardia and AF	Electrical and mechanical synchrony	62 ± 12	NA
Wu et al. 2021[15]	Prospective non-randomized	12	HBP vs. LBBaP vs. BiVP	49 vs. 32 vs. 54	LBBB	LV function and pacing metrics	30.4 ± 5.5 vs. 30.9 ± 7.3	NA
Pillai et al. 2022[17]	Retrospective	24	HBP vs. LBBaP	48 vs. 50	AF with AVN ablation	Pacing metrics	53.3 ± 9.4 vs. 53.1 ± 10.4	NA
Vijayaraman et al. 2022[18]	Prospective non-randomized	22	HBPvs. LBBaP	163 vs. 196	AV block, AF with AVN ablation	Clinical outcomes	53 ± 12 vs. 53 ± 11	NA
Tan et al. 2023[19]	Prospective non-randomized	26	HBP vs. LBBaP	147 vs. 191	SND, AV block, CRT	Pacing metrics	54 ± 14 vs. 55 ± 14	58 ± 45 vs. 57 ± 45
O'Connor et al. 2023[20]	Retrospective	NA	HBP vs. LBBaP	30 vs. 30	AV block or SND	Pacing metrics	46% vs. 54%	NA

Abbreviations: AF, atrial fibrillation; AV, atrioventricular; AVN, Atrioventricular node; BiVP, biventricular pacing; ECG, electrocardiogram; EF, ejection fraction; FU, follow-up; HBP, His bundle pacing; HFH, heart failure hospitalization; LBBaP, left bundle branch area pacing; LVEF, left ventricular ejection fraction; NA, not available; RCT, randomized control trial; SND, sick node disease.

variables, and average value, standard deviation and sample size for continuous variables) for each outcome of interest from the included studies. Differences in events rates and average values for specific outcome among groups were determined and presented using Forest plots with corresponding 95% confidence intervals (CI) for each study. The effect measure for dichotomous variables was quantified as risk ratios (RR), and for continuous variables was the mean difference (MD). Meta-analysis was conducted and the data from each study were pooled using fixed (Mantel-Haenszel, Rothman-Boice) or random effects (DerSimonian-Laird) model, as appropriate. Statistical heterogeneity between the trials was assessed using Cochran's Q test and Higgins I^2 statistic. Relevant statistical heterogeneity was present in cases where Cochran's Q test $p < .05$ and $I^2 > 50\%$, for which cases we used random-effects models. All statistical analyses were conducted by using RevMan 5.3 software. All *p*-values were two-sided, with $p < .05$ considered as significant.

3 | RESULTS

In total, 952 studies were identified from the systematic review and additional 8 were found by references review of the included articles. After removal of duplicates, 641 studies remained and were evaluated against the predefined inclusion criteria. Of those, 53 studies were included for full-text review, and a further 44 studies were excluded leaving 10 studies for the systematic review and meta-analysis (Figure 1). Of the 10 studies, 727 patients undergoing HBP were compared to 869 patients undergoing LBBaP with follow-up durations between 3 and 26 months.[11–20] The characteristics of the studies are summarized in Table 1.

Result of the comparisons analyzed as a single entity are detailed below:

3.1 | Implant success rate

Implant success rate was reported in seven studies and was significantly higher in LBBaP compared with HBP (93 % vs. 70 %) (RR 1.24, 95% CI: 1.08 to 1.42, $p = .002$) (Figure 2).

3.2 | Capture threshold at implantation and follow-up

Pacing capture threshold at implantation and during follow-up was reported in 10 studies. Capture thresholds in the LBBaP group were significantly lower compared with HBP at the time of implantation (0.62 vs. 1.27 V) (mean difference [MD] of −0.62 V, 95% CI: −0.74 to −0.51, $p < .0001$), and at follow-up up to 26 months after implantation (0.7 vs. 1.48 V) (MD of −0.74 V, 95% CI: −0.96 to −0.53, $p < .0001$) (Figure 3).

3.3 | R wave amplitude at implantation

R wave amplitude in the LBBaP group was significantly higher compared with HBP at the time of implantation (12.7 vs. 4.1 mV) (MD 8.56 mV, 95% CI: 6.78 to 10.35, $p = < .0001$) (Figure 4).

3.4 | QRS duration

The paced QRS duration was slightly decreased compared with the native QRS in the HBP (MD of −1.88 ms, 95% CI: -.17.52 to 13.76 ms, $p = .81$) and LBBaP group (−3.27 ms, 95% CI: −16.36 to 9.81 ms, $p = .62$) respectively (Figure 4). However, there was no significant difference between LBBaP and HBP in the test for subgroup difference ($p = .89$).

3.5 | Procedure and fluoroscopy duration

HPB was associated with significantly longer procedure duration compared with LBBaP (86.8 vs. 73.8 min) (MD of 14.66 min, 95% CI: 5.78 to 23.54, $p = .001$). Fluoroscopy duration was significantly shorter in LBBaP compared with HBP (9.1 vs. 13.3 min) (MD of −4.2 min, 95% CI: −8.4 to 0.0, $p = .05$) (Figure 5).

3.6 | Lead revisions

During follow up, there was no significant difference of ventricular lead revision rate in the HBP group compared with LBBaP group (2.8 vs. 2 %) (RR: 0.74, 95% CI: 0.33 to 1.62, $p = .45$) (Figure 6).

3.7 | Mortality and HFH

Compared with HBP, LBBaP was associated with a decreased risk of all-cause mortality (RR: 0.50, 95% CI: 0.33 to 0.77, $p = .002$) and no statistically significant decrease in HFH (RR: 0.57, 95% CI: 0.33 to 1.00, $p = .05$) (Figure 7).

4 | DISCUSSION

This systematic review and meta-analysis aimed to evaluate the existing evidence comparing HBP with LBBaP as a primary pacing strategy. We found that compared with HBP, LBBaP was associated with higher implant success rate and better pacing metrics including lower capture threshold at implantation and at follow-up and shorter procedure duration. Compared with HBP, LBBaP was associated with a slightly decreased risk of all-cause mortality and HFH. We are not aware of other studies that have synthesized comparative evidence for these techniques with such a number of patients.

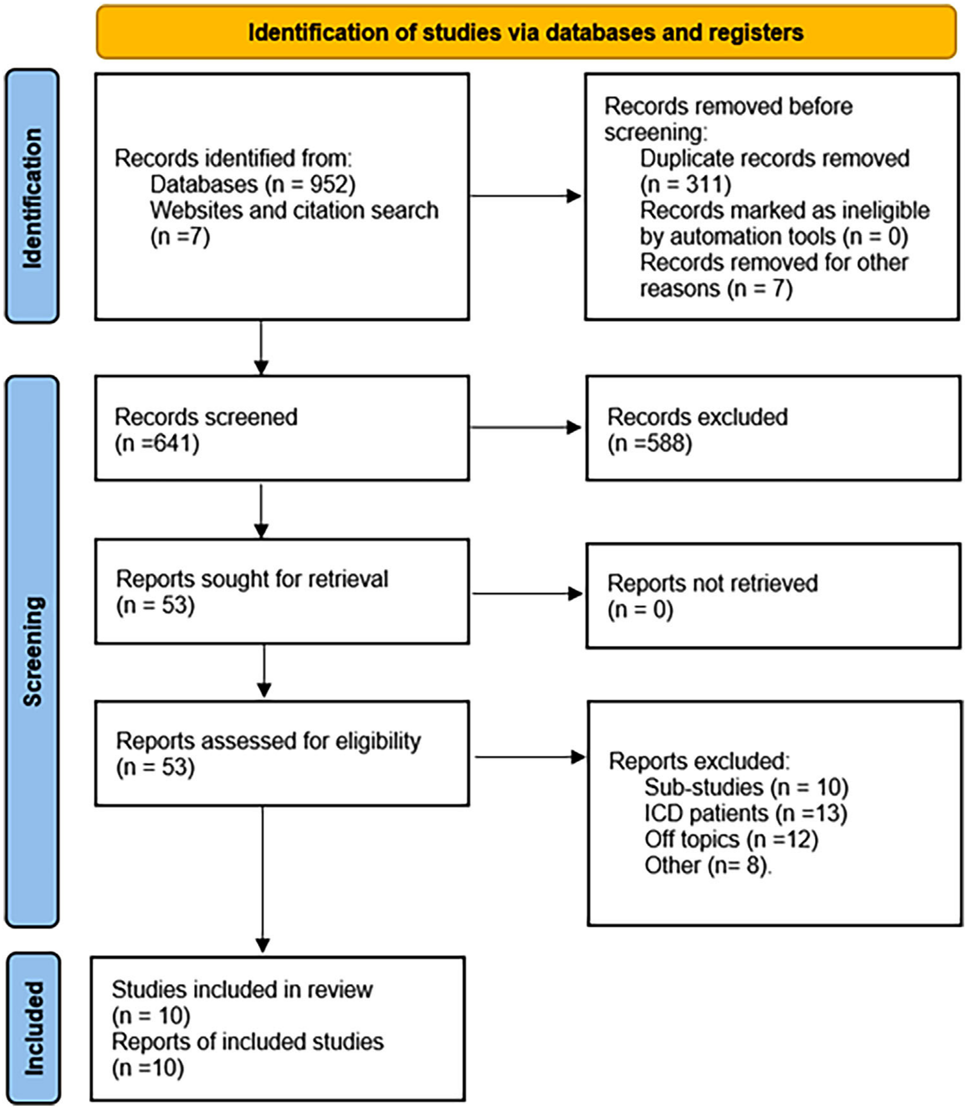


FIGURE 1 PRISMA flowchart for the studies included and reasons for studies excluded from the systematic review. ICD, implantable cardioverter defibrillator. [Color figure can be viewed at wileyonlinelibrary.com]

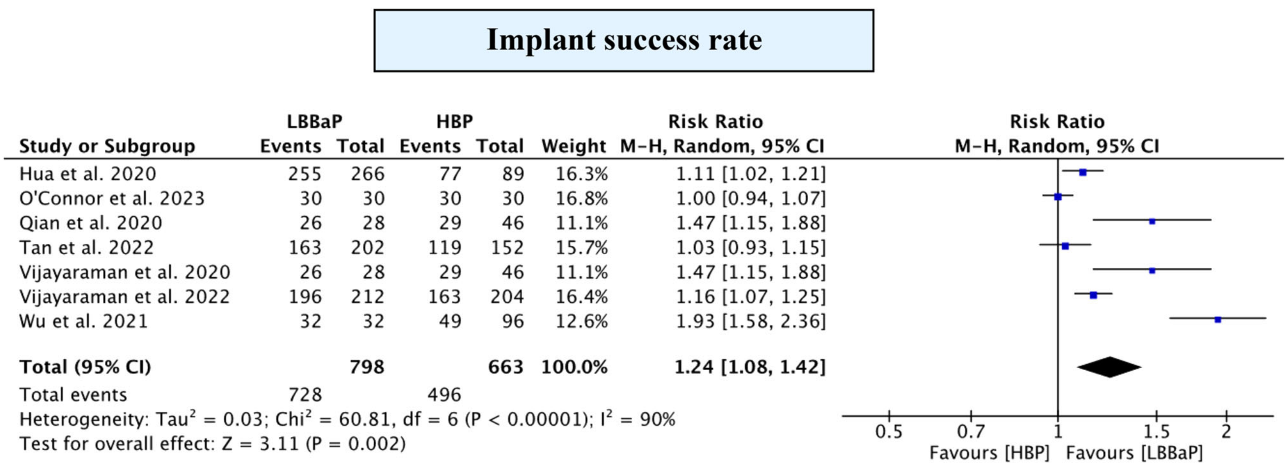
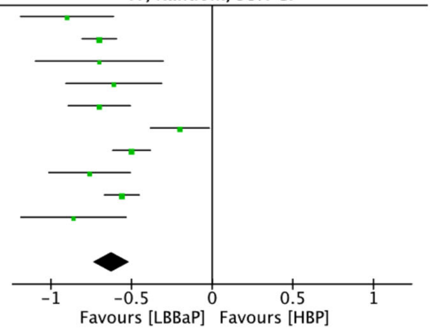


FIGURE 2 Forest plot of implant success rate with LBBaP versus HBP for patients requiring permanent transvenous pacing. CI, confidence interval; HBP, His-bundle pacing; LBBaP: left bundle brunch area pacing, RR, risk reduction. [Color figure can be viewed at wileyonlinelibrary.com]

Pacing threshold at implantation

Study or Subgroup	LBBaP Mean	LBBaP SD	LBBaP Total	HBP Mean	HBP SD	HBP Total	Weight	Mean Difference IV, Random, 95% CI
Hou et al. 2019	0.5	0.1	56	1.4	0.8	29	7.9%	−0.90 [−1.19, −0.61]
Hua et al. 2020	0.6	0.2	126	1.3	0.6	125	13.8%	−0.70 [−0.81, −0.59]
O'Connor et al. 2023	0.7	0.5	30	1.4	1	30	5.5%	−0.70 [−1.10, −0.30]
Pillai et al. 2022	0.68	0.27	50	1.29	1.03	48	7.7%	−0.61 [−0.91, −0.31]
Qian et al. 2020	0.5	0.1	185	1.2	0.8	64	10.9%	−0.70 [−0.90, −0.50]
Sheng et al. 2021	0.8	0.3	20	1	0.3	20	11.2%	−0.20 [−0.39, −0.01]
Tan et al. 2022	0.7	0.3	191	1.2	0.7	147	13.4%	−0.50 [−0.62, −0.38]
Vijayaraman et al. 2020	0.64	0.3	28	1.4	0.8	46	8.9%	−0.76 [−1.02, −0.50]
Vijayaraman et al. 2022	0.62	0.27	196	1.18	0.69	163	13.7%	−0.56 [−0.67, −0.45]
Wu et al. 2021	0.49	0.13	26	1.35	0.9	29	6.9%	−0.86 [−1.19, −0.53]
Total (95% CI)			**908**			**701**	**100.0%**	**−0.62 [−0.74, −0.51]**

Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 33.13$, df = 9 (P = 0.0001); $I^2 = 73\%$
Test for overall effect: Z = 10.47 (P < 0.00001)



Pacing threshold at follow-up

Study or Subgroup	LBBaP Mean	LBBaP SD	LBBaP Total	HBP Mean	HBP SD	HBP Total	Weight	Mean Difference IV, Random, 95% CI
Hou et al. 2019	0.6	0.1	56	1.5	0.8	29	11.7%	−0.90 [−1.19, −0.61]
Hua et al. 2020	0.63	0.19	126	1.26	0.83	125	13.9%	−0.63 [−0.78, −0.48]
Pillai et al. 2022	0.76	0.15	50	1.6	1.13	48	11.2%	−0.84 [−1.16, −0.52]
Qian et al. 2020	0.7	0.1	185	1.4	0.8	64	13.3%	−0.70 [−0.90, −0.50]
Tan et al. 2022	0.8	0.3	191	1.6	1.1	147	13.5%	−0.80 [−0.98, −0.62]
Vijayaraman et al. 2020	0.52	0.1	28	1.8	1.7	46	8.4%	−1.28 [−1.77, −0.79]
Vijayaraman et al. 2022	0.83	0.25	196	1.1	0.54	163	14.5%	−0.27 [−0.36, −0.18]
Wu et al. 2021	0.8	0.3	191	1.6	1.1	147	13.5%	−0.80 [−0.98, −0.62]
Total (95% CI)			**1023**			**769**	**100.0%**	**−0.74 [−0.96, −0.53]**

Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 71.88$, df = 7 (P < 0.00001); $I^2 = 90\%$
Test for overall effect: Z = 6.75 (P < 0.00001)

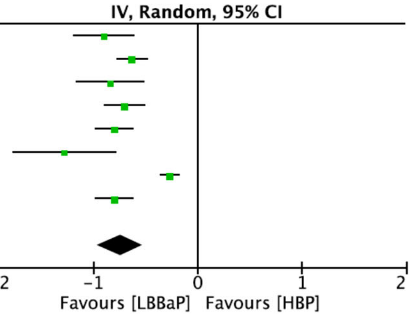


FIGURE 3 Forest plot of change in pacing threshold at implantation and at follow-up among LBBaP and HBP groups. CI, confidence interval; HBP, His-bundle pacing, LBBaP, left bundle branch area pacing; RR, risk reduction. [Color figure can be viewed at wileyonlinelibrary.com]

The risk of pacemaker-induced cardiomyopathy is associated with a high burden of pacing of the RV and can occur in up to 25 % of patients during follow-up.[3–5] Many previous studies indicated potential advantages of conduction system pacing over conventional RVP as a first-line approach for patients requiring permanent pacing.[4,6,7] In a recent meta-analysis, HBP compared to RVP as an initial pacing strategy for patients requiring a permanent pacemaker was associated with a decrease in HFH rate, a decrease in the duration of the paced QRS complex and a preservation of the LVEF, though this was at the expense of higher rates of lead revision and prolonged procedure and fluoroscopy duration.[4] This study also found that LBBaP was associated with a shorter paced QRS complex duration compared with RVP, with no differences in pacing metrics. Of note, the difference in mortality and HFH must be interpreted with caution, until the point that robust evidence is provided.

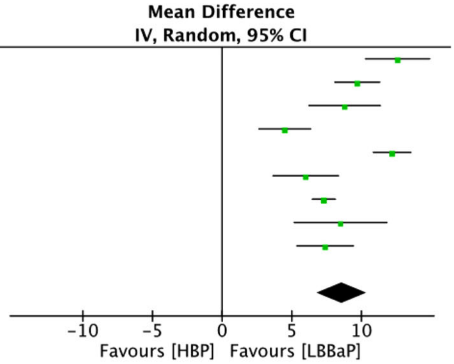
Ventricular activation via HBP is the most physiological stimulation modality, but its widespread applicability is limited due to difficulties in electrode fixation since the His region varies among patients and lead screwing depends on locating the His bundle, which is not always visible.[6,8] Additionally, HBP may fail in some patients due to anatomical variation, enlarged right atrium, inability to locate the His bundle, or unacceptably high thresholds.[12,13] On the other hand, LBBaP may be simpler with high implantation success and stable pacing parameters.[12,14] LBBaP mainly depends on the widespread distribution of conduction tissue in the left-sided intraventricular septum. In addition, due to the surrounding myocardium of the LBBaP lead, R-wave sensing amplitude is high and the myocardial capture threshold is low.[12–16] However, there was a paucity of information about efficacy and safety for these pacing-modalities compared to each other. Moreover, LBBaP involves a high variation in lead targets– from the stem of LBB to to fascicles and even the deep septal myocardium (without direct capture of conduction tissue), as defined in a recent EHRA CSP consensus document.[21] There is a substantial difference in QRS morphology between these entities, but there are no data if this has any clinical impact.

A recent meta-analysis compared pacing parameters and clinical results between HBP and LBBaP.[22] It showed that pacing characteristics are better in LBBaP compared with HBP. No statistical differences were found in LVEF improvement and native QRS duration versus paced QRS duration at implantation. However, the studies included in this analysis reported small number of patients. Our analysis included a significantly larger cohort of patients and newer studies with longer

R wave amplitude at implantation

Study or Subgroup	LBBaP Mean	LBBaP SD	LBBaP Total	HBP Mean	HBP SD	HBP Total	Weight	Mean Difference IV, Random, 95% CI
Hou et al. 2019	17	6.7	56	4.4	4.3	29	10.7%	12.60 [10.25, 14.95]
Hua et al. 2020	12.5	9	126	2.8	3	125	11.8%	9.70 [8.04, 11.36]
O'Connor et al. 2023	12	6.4	30	3.2	3.5	30	10.3%	8.80 [6.19, 11.41]
Pillai et al. 2022	9.8	5.5	50	5.3	4	48	11.5%	4.50 [2.60, 6.40]
Qian et al. 2020	16.5	7.5	185	4.3	3.6	64	12.2%	12.20 [10.81, 13.59]
Sheng et al. 2021	9.7	4.5	20	3.7	3.1	20	10.6%	6.00 [3.61, 8.39]
Tan et al. 2022	11.9	5.2	191	4.6	2.9	147	12.8%	7.30 [6.43, 8.17]
Vijayaraman et al. 2020	14	8	28	5.5	5.6	46	8.9%	8.50 [5.12, 11.88]
Wu et al. 2021	11.2	5.1	26	3.8	1.9	29	11.2%	7.40 [5.32, 9.48]
Total (95% CI)			**712**			**538**	**100.0%**	**8.56 [6.78, 10.35]**

Heterogeneity: $Tau^2 = 6.29$; $Chi^2 = 70.26$, df = 8 (P < 0.00001); $I^2 = 89\%$
Test for overall effect: Z = 9.41 (P < 0.00001)



QRS duration before and after implantation

Study or Subgroup	After pacing Mean	After pacing SD	After pacing Total	Before pacing Mean	Before pacing SD	Before pacing Total	Weight	Mean Difference IV, Random, 95% CI
1.7.1 HBP								
Hou et al. 2019	99.1	18.4	29	100.6	20.3	29	11.0%	−1.50 [−11.47, 8.47]
Hua et al. 2020	108.5	24.4	125	105.9	24.4	125	11.3%	2.60 [−3.45, 8.65]
Pillai et al. 2022	119.6	19.2	48	97.7	24	48	11.1%	21.90 [13.21, 30.59]
Qian et al. 2020	110.5	24.4	64	103.5	20.2	64	11.2%	7.00 [−0.76, 14.76]
Sheng et al. 2021	96.5	16.2	20	104.5	22.3	20	10.8%	−8.00 [−20.08, 4.08]
Tan et al. 2022	114	22	147	110	28	147	11.3%	4.00 [−1.76, 9.76]
Vijayaraman et al. 2020	144	27	46	134	30	46	10.8%	10.00 [−1.66, 21.66]
Vijayaraman et al. 2022	125	20.2	163	109	26.8	163	11.4%	16.00 [10.85, 21.15]
Wu et al. 2021	100.7	15.3	29	170.3	19.3	29	11.1%	−69.60 [−78.56, −60.64]
Subtotal (95% CI)			**671**			**671**	**100.0%**	**−1.88 [−17.52, 13.76]**
Heterogeneity: $Tau^2 = 553.14$; $Chi^2 = 300.59$, df = 8 (P < 0.00001); $I^2 = 97\%$								
Test for overall effect: Z = 0.24 (P = 0.81)								
1.7.2 LBBaP								
Hou et al. 2019	117.8	25.2	56	108.5	28.8	56	10.8%	9.30 [−0.72, 19.32]
Hua et al. 2020	108.3	25.5	126	111.4	23.1	126	11.2%	−3.10 [−9.11, 2.91]
Pillai et al. 2022	122	8.4	50	102.7	20.5	50	11.2%	19.30 [13.16, 25.44]
Qian et al. 2020	116.4	9.1	185	109.4	27.9	185	11.4%	7.00 [2.77, 11.23]
Sheng et al. 2021	113	14.5	20	96.5	16.2	20	10.8%	16.50 [6.97, 26.03]
Tan et al. 2022	110	28	191	113	35	191	11.2%	−3.00 [−9.36, 3.36]
Vijayaraman et al. 2020	125	15	55	144	27	55	11.0%	−19.00 [−27.16, −10.84]
Vijayaraman et al. 2022	126	23.5	196	127	30.5	196	11.3%	−1.00 [−6.39, 4.39]
Wu et al. 2021	110.8	11.1	26	166.2	16.2	26	11.1%	−55.40 [−62.95, −47.85]
Subtotal (95% CI)			**905**			**905**	**100.0%**	**−3.27 [−16.36, 9.81]**
Heterogeneity: $Tau^2 = 387.21$; $Chi^2 = 291.74$, df = 8 (P < 0.00001); $I^2 = 97\%$								
Test for overall effect: Z = 0.49 (P = 0.62)								

Test for subgroup differences: $Chi^2 = 0.02$, df = 1 (P = 0.89), $I^2 = 0\%$

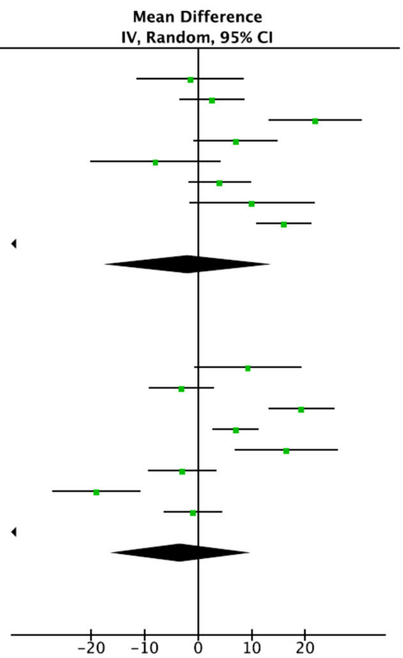


FIGURE 4 Forest plot of R wave amplitude at implantation among LBBaP and HBP groups. Forest plot of change in QRS duration before and after implantation among HBP and LBBaP groups. CI, confidence interval; HBP, His-bundle pacing; LBBaP, left bundle branch area pacing; RR, risk reduction. [Color figure can be viewed at wileyonlinelibrary.com]

follow-up period.[17–20] In addition, our study reports data on lead revision that has not been previously reported.

Our results indicate the potential advantages of LBBaP over HBP for patients requiring permanent pacing. From observational data, we found that LBBaP is potentially superior to HBP as a first-line approach in terms of pacing performance and reliability with potentially reduced adverse events compared to HBP, and advocates that LBBaP is the preferred conduction system pacing modality. Moreover, the shorter learning curve, greater success in infranodal AV block, and superior electrical characteristics have led to wider adoption of LBBaP in clinical practice compared to HBP.[12–16,23] As well, the pacing threshold and R-wave amplitude were significantly better with LBBaP than with HBP, reducing the risk of loss of capture and sensory problems during long-term follow-up. This can additionally impact battery longevity during long-term follow-up.

4.1 | Limitations

First, the studies included in the meta-analysis had small numbers of patients, different follow-up periods and importantly, were non-randomized. Therefore, it is difficult to draw a clear and solid

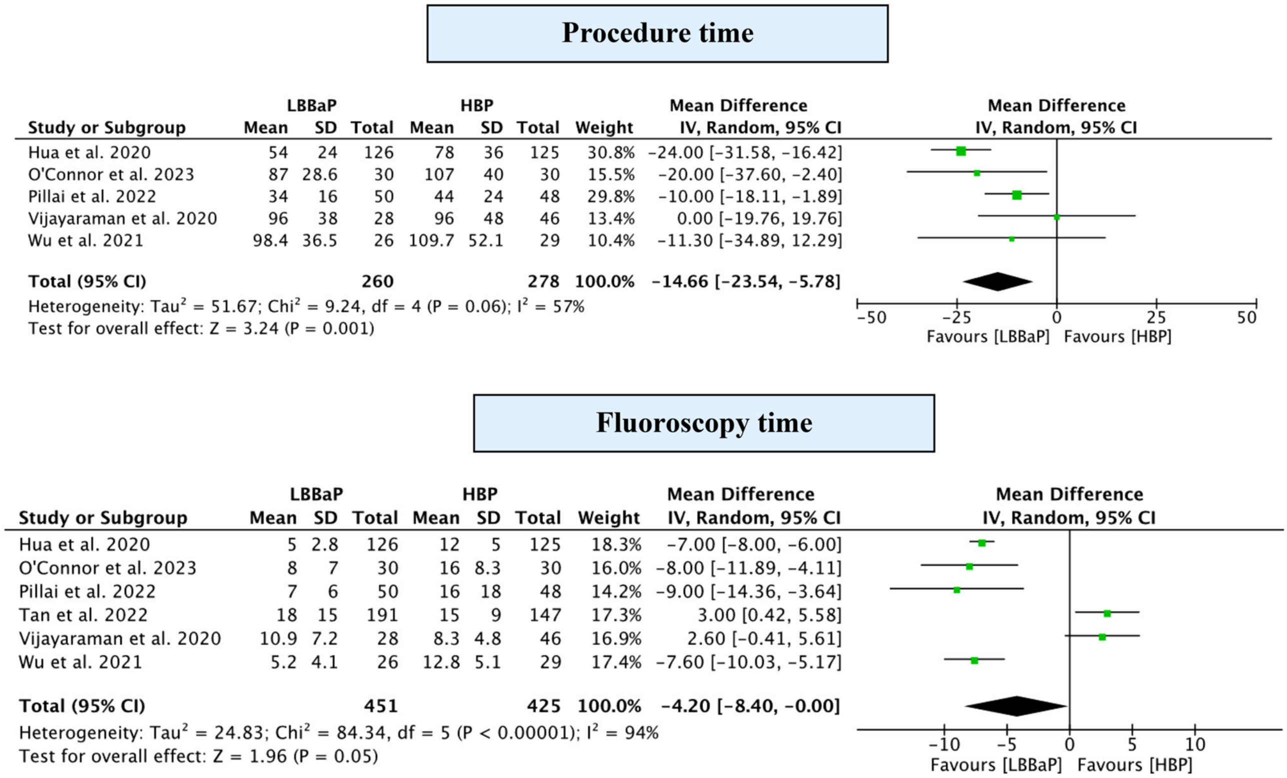


FIGURE 5 Forest plot of procedure and fluoroscopy among HBP and LBBaP groups. CI, confidence interval; HBP, His-bundle pacing; LBBaP, left bundle branch area pacing; RR, risk reduction. [Color figure can be viewed at wileyonlinelibrary.com]

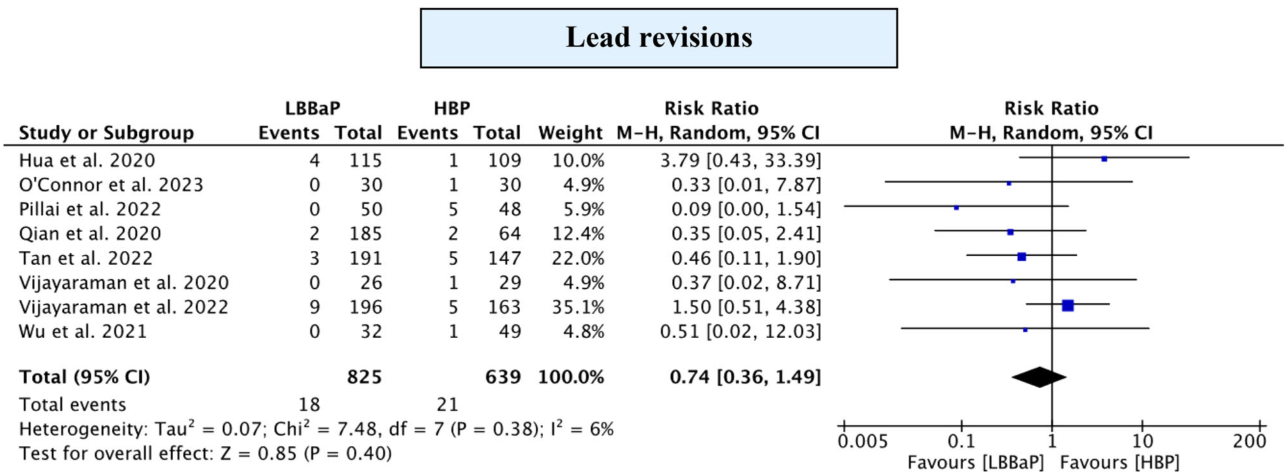


FIGURE 6 Forest plot of lead revisions rate among HBP and LBBaP groups. CI, confidence interval; HBP, His-bundle pacing; LBBaP, left bundle branch area pacing; RR, risk reduction. [Color figure can be viewed at wileyonlinelibrary.com]

conclusion about the superiority of one strategy over another. Second, the variation in the definitions and pacing indications between studies, particularly in relation to exposure or outcome measures, might have caused misclassification bias. As such, investigations were performed in patients with various pacemaker indications. Moreover, many of the studies included in this meta-analysis included patients with different pacing indications and, unfortunately, almost all studies lack separate data for outcomes stratified by indication and data on pacing burden. Unfortunately, it was not possible to provide complete data on the consistency of the duration of the procedure (skin-to-skin vs. associated with ventricular electrode placement) as there is no clear data on this point in all included papers. A sub-analysis according to pacing indications, LVEF and pacing burden would therefore not be possible. Due to the lack of separate data on QRS morphology and the

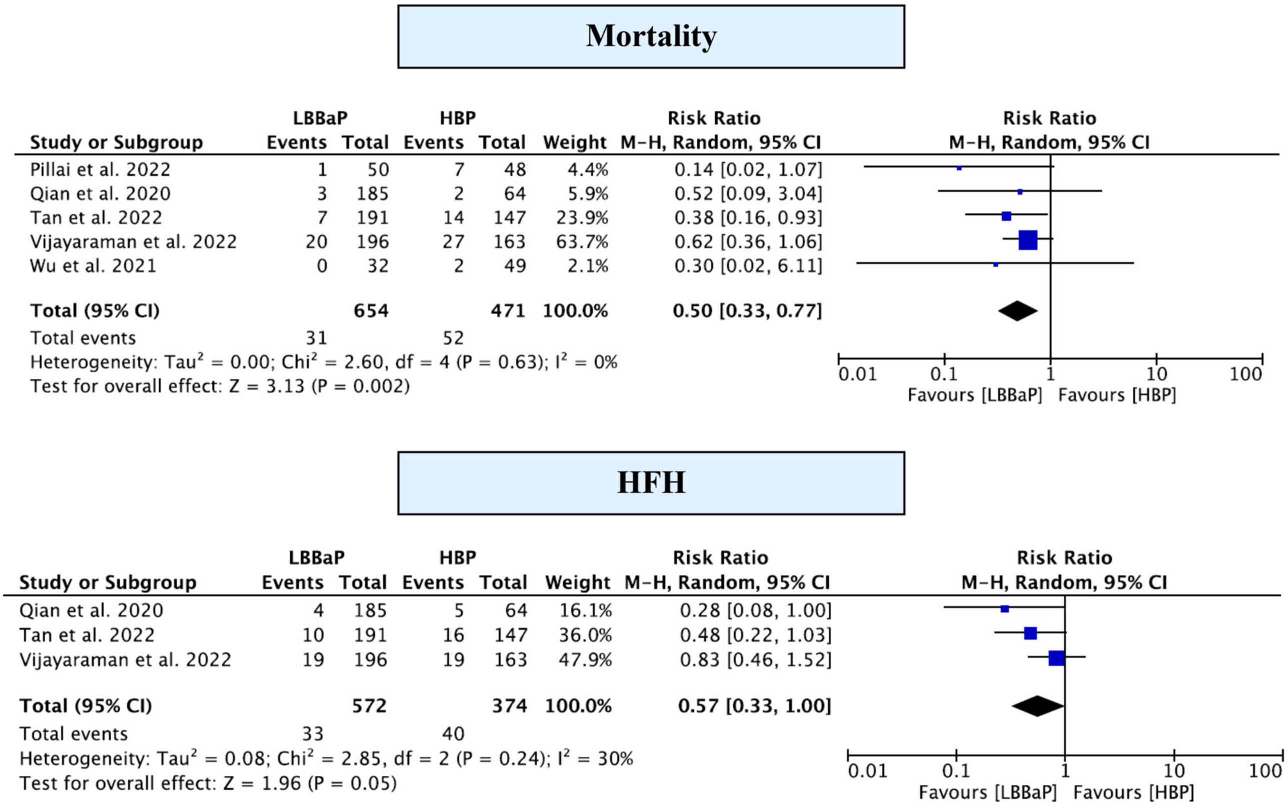


FIGURE 7 Forest plot of all-cause mortality and HFH with HBP versus LBBaP for patients requiring permanent transvenous pacing after 22 months follow-up. CI, confidence interval; HBP, His-bundle pacing; HFH, heart failure hospitalization; LBBaP, left bundle branch area pacing, RR, risk reduction. [Color figure can be viewed at wileyonlinelibrary.com]

very small number of patients based on all included studies, it was not possible to stratify the patients by QRS morphology and duration.

5 | CONCLUSION

Among patients undergoing de novo transvenous pacemaker implantation for bradyarrhythmia, an initial strategy of LBBaP compared with HBP was associated with higher implant success rate and better pacing metrics in different but rather short follow-up duration periods. Randomized studies with robust data are needed to compare clinical outcome benefits for both strategies.

ACKNOWLEDGMENTS

M.B. is supported by the Deutsche Forschungsgemeinschaft (German Research Foundation; TTR 219, project number 322900939).

Open access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST STATMENT

A.A., J.G., D.V., and C.W.: None. N.S.: Speaker's bureau honoraria from Abbott, Medtronic, AstraZeneca, Bayer; travel grants from Biotronik, Johnson and Johnson, and Pfizer. H.B.: Has received speaker fees and institutional fellowship support/research grants from Abbott, Biotronik, Boston Scientific, Medtronic, and Microport. J.L.M.: Has received honoraria for lectures, scientific advice and education from Abbott, Biotronik, Medtronic and Microport.

M.B.: Reports personal fees from Abbott, Amgen, Astra Zeneca, Bayer, Boehringer Ingelheim, Cytokinetics, Medtronic, Novartis, Servier, and Vifor. C.U.: Has received honoraria for lectures and scientific advice from Aurigen Medical, Bayer, Boehringer-Ingelheim, Medtronic, Pfizer, and ReCor Medical.

DATA AVAILABILITY STATEMENT

The data underlying this article are available in the article and in its online supplementary material.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Abdin A, Werner C, Burri H, et al. Outcomes of left bundle branch area pacing compared to His bundle pacing as a primary pacing strategy: Systematic review and meta-analysis. *Pacing Clin Electrophysiol*. 2023;46:1315–1324. https://doi.org/10.1111/pace.14836