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Left Bundle Branch Area Pacing Versus Right Ventricular Pacing in Patients With Atrioventricular Block: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Left bundle branch area pacing (LBBAP) is a new technique for patients with atrioventricular block (AVB) and preserved left ventricular ejection fraction (LVEF), potentially offering better cardiac function than right ventricular pacing (RVP).

Methods: We searched databases and registries for studies that compared LBBAP with RVP in patients with AVB and preserved LVEF. We extracted data on various outcomes and pooled the effect estimates using random-effects models.

Results: Our meta-analysis included 14 studies (10 observational and 4 RCTs) involving 3062 patients with AVB. The analysis revealed that the QRS duration was significantly shorter in the LBBAP group compared to the RVP group [MD = −35.56 ms; 95% CI: (−39.27, −31.85), $p < 0.00001$]. Patients in the LBBAP group also exhibited a significant increase in left ventricular ejection fraction (LVEF) [MD = 5.48%; 95% CI: (4.07%, 6.89%), $p < 0.00001$], and a significant reduction in left ventricular end-diastolic diameter (LVEDD) compared to RVP [MD = −3.98 mm; 95% CI: (−5.88, −2.09 mm), $p < 0.0001$]. In terms of clinical outcomes, LBBAP was associated with a significantly lower risk of heart failure hospitalizations (HFHs) compared to RVP [OR = 0.26; 95% CI: (0.16, 0.44), $p < 0.0001$]. However, no significant differences were observed between the two groups in the implant success rate, pacing impedance, or pacing threshold. The RVP group demonstrated a significantly higher R-wave amplitude increase than the LBBAP group [MD = 0.85 mV; 95% CI: (0.23, 1.46), $p = .007$]. Lastly, there was no significant difference in the incidence of complications between the two groups [OR = 2.12; 95% CI: (0.29, 15.52), $p = 0.46$].

Conclusion: LBBAP outperforms RVP in several cardiac function indicators, suggesting it may be a superior pacing method for AVB patients with preserved LVEF. However, the small sample size in studies and the result in heterogeneity call for more research to validate these findings and assess LBBAP's long-term effects.

Abbreviations: AV, atrioventricular; AVB, atrioventricular block; CI, confidence intervals; CRT, cardiac resynchronization therapy; ESC, European Society of Cardiology; EU, European Union; HFH, heart failure hospitalization; LBBAP, left bundle branch area pacing; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; MD, mean difference; MeSH, medical subject headings; OR, odds ratios; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT, randomized controlled trial; RVP, right ventricular pacing; WHO, World Health Organization.

1 | Introduction

Cardiac pacing therapy for atrioventricular heart block, which began in the late 1950s, has evolved with various pacing techniques introduced over the years [1, 2]. Recently, left bundle branch area pacing (LBBAP) has emerged as a promising alternative for cardiac resynchronization therapy (CRT) [3]. Studies have demonstrated that LBBAP offers improvements in cardiac function, including reductions in left ventricular end-systolic volume, QRS duration, and pacing threshold, alongside a decrease in adverse outcomes [3–5].

Chronic right ventricular pacing (RVP), on the other hand, has been associated with detrimental effects on the heart, including heart failure, disruption of normal electrical and mechanical function, increased risk of atrial fibrillation, and higher mortality rates [6, 7]. Despite these risks, the European Society of Cardiology (ESC) guidelines continue to recommend RVP over LBBAP for certain patients due to insufficient large-scale evidence proving LBBAP's superiority [8]. While LBBAP has shown promise in smaller studies, more robust data are needed to support a shift in clinical practice.

2 | Methods

2.1 | Data Sources and Search Strategy

This meta-analysis was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) guidelines to ensure transparency and rigor in reporting [9]. A comprehensive literature search was executed to identify relevant observational studies and controlled trials. The search was systematically performed on electronic databases, including PubMed, Cochrane CENTRAL, and Scopus. The inclusion criteria were limited to articles published in English from the inception of each database to November 2023.

The search strategy employed a combination of keywords and their corresponding MeSH (Medical Subject Headings) terms: "(left bundle branch area pacing OR LBBAP OR right ventricular pacing OR RVP OR cardiac resynchronization therapy OR CRT) AND (atrioventricular heart block OR bradycardia OR heart block)." The Supporting Information provides a detailed breakdown of the search strategy.

The WHO International Clinical Trials Register, the EU Clinical Trials Register, and clinicaltrials.gov were diligently queried to ensure thoroughness and minimize the risk of overlooking relevant data. This approach aimed to prevent redundancy in data collection and identify any potentially missed completed clinical trials.

2.2 | Study Selection

The inclusion criteria for article selection were carefully defined as follows:

1. Retrospective and prospective observational studies and randomized controlled trials (RCTs) were considered for inclusion in this meta-analysis. These studies specifically compared two pacing methods: RVP as the control group and LBBAP as the experimental group.
2. The selected studies focused on patients with heart blocks and sick node sinus, specifically those with preserved ejection fraction (pEF).

Following was described as the exclusion criteria:

1. All the editorials, case reports, case series, and short communications were considered ineligible for the study.
2. Studies that did not report quality outcomes were excluded.
3. Studies that did not report the decided outcomes were excluded.

2.3 | Data Extraction and Assessment of Study Quality

Upon retrieval, the collected articles underwent a meticulous deduplication process using RefWorks to eliminate redundant data. The subsequent screening involved thoroughly evaluating the articles based on their relevance to the topic, focusing on the abstracts. Following this initial screening, a detailed analysis was conducted for article selection, guided by predefined eligibility criteria.

To enhance the robustness and objectivity of the selection process, two independent reviewers, I.A. and M.K.K., were assigned to assess each article meticulously. The predefined eligibility criteria guided the reviewers in determining the suitability of the studies for inclusion in the meta-analysis.

The primary outcomes of interest encompassed key parameters, including QRS duration, left ventricular end-diastolic diameter (LVEDD), pacing impedance, heart failure hospitalization (HFH), improvement in R-wave amplitudes, left ventricular ejection fraction (LVEF), and pacing threshold. To ensure a comprehensive evaluation of study quality, we employed the Cochrane risk of bias assessment for RCTs and the Newcastle–Ottawa Scale assessment for cross-sectional studies.

2.4 | Statistical Analysis

The statistical analysis was performed utilizing RevMan software [10], ensuring a robust and standardized approach. Results were presented as odds ratios (ORs) accompanied by 95% confidence intervals (CIs), employing a random-effects model to account for potential variability across studies. Forest plots were instrumental in providing a visual representation of the outcomes. To gauge the degree of heterogeneity among the included studies, the Higgins I^2 test was employed, with a threshold exceeding 50% indicative of substantial heterogeneity. This assessment contributed to a nuanced interpretation of the overall consistency or variability in the study results.

In addition, to assess potential publication bias, we conducted Begg's test and visually inspected the results using funnel plots.

These analyses served as necessary supplementary measures to ensure the robustness and reliability of our findings. Statistical significance was established at *p* values below 0.05, reinforcing the rigor of our analytical approach.

3 | Results

A comprehensive analysis was conducted, synthesizing data from a total of 14 studies (10 non-randomized studies and four RCTs) to scrutinize the comparative outcomes between RVP and LBBAP [11–24]. The pacing burden was reported in four studies [11, 13, 17, 18], and it averaged around 90%. Both pacing modalities are frequently employed for addressing heart blocks, and this meta-analysis aims to discern their respective benefits in specific clinical domains.

The study selection process involved thoroughly exploring various databases and registers to extract pertinent data. Stringent inclusion criteria were applied to ensure that selected studies were conducive to the objectives of this analysis. Initially screening through 5380 studies, a meticulous screening through title, abstract, full text, and reference screening ultimately identified 10 observational studies and four RCTs meeting the inclusion criteria. The evaluation of these studies adhered to the PRISMA guidelines [9], as depicted in the PRISMA flowchart (Figure 1).

The total sample comprised 3062 patients, with a mean age of 69.85 ± 10.74 years, a mean left ventricular ejection fraction (LVEF) of 60.08%, and an average follow-up duration of 12 months. Further details regarding the populations for each intervention and study are elucidated in Table 1.

3.1 | Pacing QRS Duration

Data from 11 studies were analyzed to assess the average QRS duration at the conclusion of the study for both LBBAP and RVP. This analysis included a total of 2877 patients. The results indicated that QRS duration was significantly lower in the

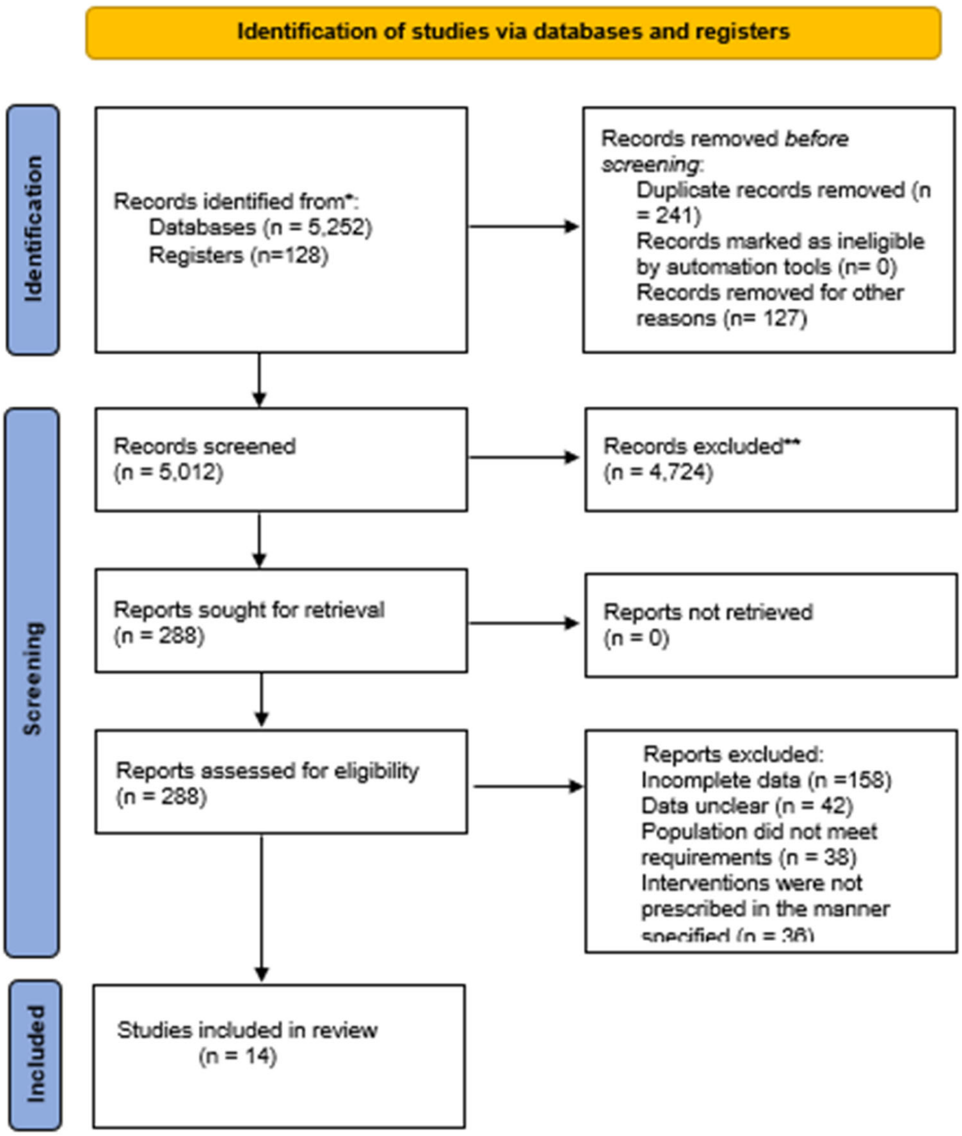

FIGURE 1 | PRISMA flowchart.

TABLE 1 | Baseline characteristics table.

References	Sample size	Study design	Males, N (%)	Age, n (SD)	Follow-up	LVEF, %	Baseline QRS duration (ms)
Cai et al. [14]	LBBP—40 RVP—38	Observational study	13 (33) 14 (37)	65.93 ± 9.99 68.61 ± 9.83	NR	NR	91.06 ± 14.17 83.75 ± 14.82
Chen et al. [15]	LBBP—20 RVP—20	Prospective observational study	7 (35) 9 (45)	66.90 ± 7.49 71.65 ± 7.80	3 months	60.00 ± 10.60 60.70 ± 6.08	110.00 ± 33.38 106.25 ± 21.53
Li et al. [11]	LBBAP— 246 RVP—120	Prospective observational study	161 (65) 81 (67.5)	63.3 ± 15 62.1 ± 17.2	11.4 ± 2.7 months	61.7 ± 7.4 61.5 ± 6.4	115.9 ± 26.7 117.9 ± 27.9
Riano Ondiviela et al. [12]	LBBP—60 LBBAP—60	Randomized control trial	62 (37) 60 (36)	76.7 ± 9 79.7 ± 8	3 months	NR	112,6 ± 29.6 109,9 ± 25.8
Wang et al. [16]	LBBAP—66 RVP—65	Randomized control trial	38 (57.6) 41 (63.1)	71.12 ± 13.14 72.03 ± 12.11	6 months	61.3 ± 5.7 62.1 ± 6.3	99.24 ± 13.60 101.88 ± 11.72
Zhang et al. [13]	LBBP—29 RVP—37	Reterospective observational	13 (44.83%) 17 (45.95%)	63.60 ± 8.80 67.40 ± 8.81	LBBP— 17.40 ± 3.41 months RVP— 18.00 ± 3.30 months	55.08 ± 4.32 56.29 ± 5.40	104.83 ± 15.41 98.86 ± 7.33
Sharma et al. [17]	LBBAP—321 RVP—382	Observational study	168 (52.3) 200 (52.4)	75.33 ± 12.26 74.96 ± 11.85	583 ± 274 days	59.08 ± 7.71 59.39 ± 6.55	116.56 ± 30.61 116.68 ± 29.66
Chen et al. [18]	LBBP—237 RVP—317	Observational study	130 (54.85) 157 (49.53)	67.76 ± 13.29 69.15 ± 11.48	18 months	NR NR	117.09 ± 25.82 105.04 ± 12.18
Das et al. [19]	LBBAP—22 RVP—28	Randomized control trial	NR NR	63.36 ± 7.82 61.64 ± 5.90	6 months	61.15 ± 4.04 62.50 ± 4.00	131.64 ± 17.80 132.73 ± 16.71
Liu et al. [20]	LBBAP—33 RVP—21	Retrospective observational study	21 (63.6) 11 (52.4)	73.67 ± 11.87 68.14 ± 11.66	LBBAP 13.94 ± 4.44 months RVSP 13.56 ± 4.64 months	64.97 ± 6.15 63.57 ± 9.98	113.58 ± 21.22 113.48 ± 21.80
Miyajima et al. [21]	LBBAP—39 RVP—42	Retrospective observational study	20 (51) 24 (57)	78 ± 10 79 ± 11		65 ± 6.6 63 ± 10	NR
Niu et al. [22]	LBBP—20 RVP—30	Prospective observational study	Overall 39 (65)	Overall 78.2 ± 5.4	15.0 ± 9.1 months	51.9 ± 8.5 52.3 ± 9.3	133.8 ± 32.9 134.9 ± 30.6
Yao et al. [23]	LBBAP—25 RVP—25	Randomized control trial	NR	66.3 ± 11 69.2 ± 12.8	18 months	52.48 ± 4.4 53.24 ± 3.57	139.44 ± 10.07 140.28 ± 8.93
Zhu et al. [24]	LBBAP—406 RVP—313	Prospective observational study	197 (48.5%) 150 (47.9%	64.9 ± 14.3 67.5 ± 12.2	13.6 ± 7.8 months	61.2 ± 7.27 62.5 ± 4.14	112.4 ± 24.1 98.0 ± 18.3

Abbreviations: LBBAP = left bundle branch area pacing, LBBP = left bundle branch pacing, NR = not reported, RVP = right ventricular pacing.

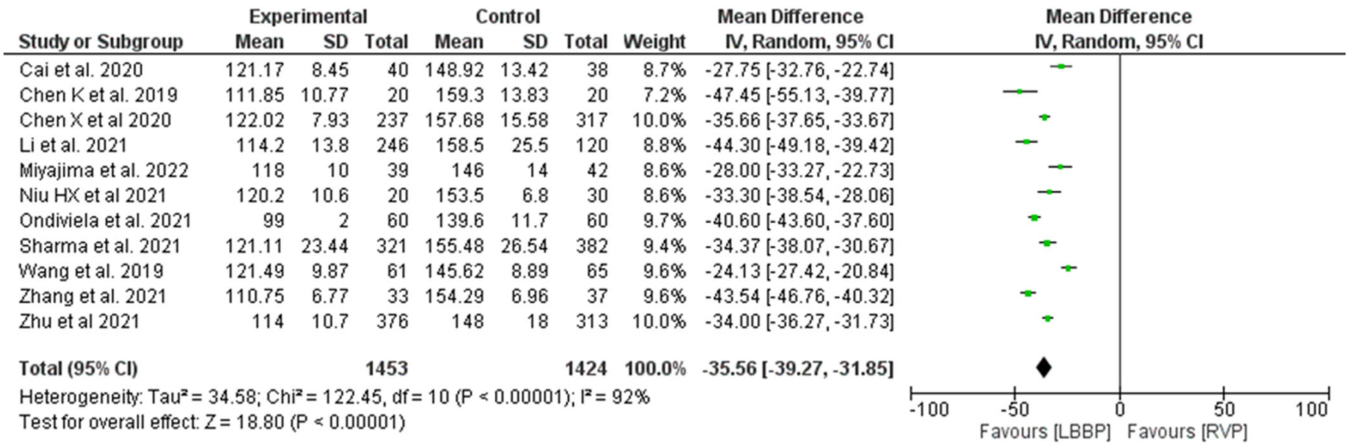

FIGURE 2 | Forest plot representing pacing QRS duration.

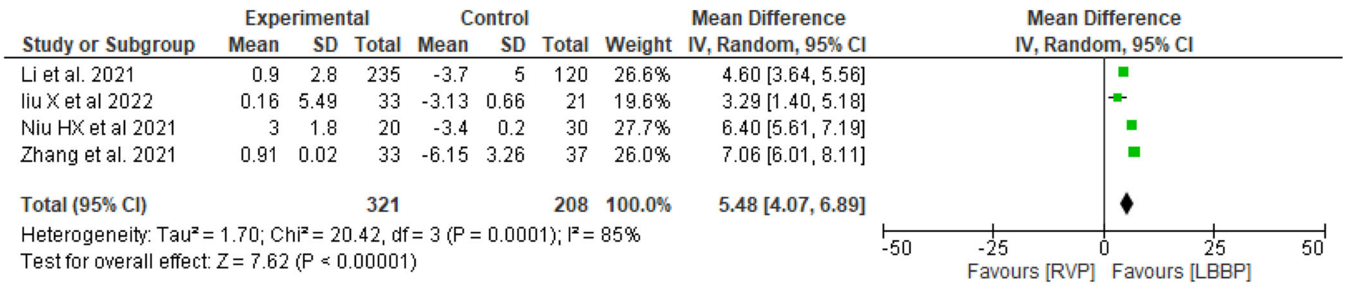

FIGURE 3 | Forest plot for LVEF at follow-up.

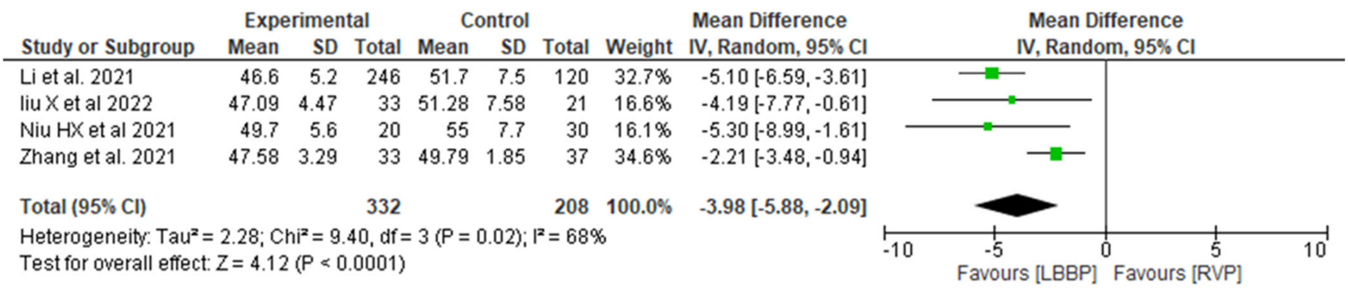

FIGURE 4 | Forest plot representing LVEDD.

LBBAP group compared to the RVP group [MD = −35.56 ms; 95% CI: (−39.27, −31.85), $p < 0.00001$] (Figure 2). Heterogeneity analysis showed no specific study as a major source of heterogeneity.

3.2 | Left Ventricular Ejection Fraction (LVEF)

The analysis of LVEF included a cohort of 529 patients from four studies comparing pacing therapies. A significant difference was observed, with patients in the LBBAP group showing higher ejection fraction values compared to those in the RVP group [MD = 5.48%; 95% CI: (4.07%, 6.89%), $p < 0.00001$] (Figure 3). The heterogeneity among the studies was substantial, suggesting considerable variability in the results. Sensitivity analysis revealed that the study by Liu et al. [20] primarily contributed to this heterogeneity.

3.3 | LVEDD

The evaluation of LVEDD included four studies involving 540 patients receiving pacing therapies. The analysis showed a significant difference between groups, with patients in the LBBAP group demonstrating a lower LVEDD compared to those in the RVP group [MD = −3.98 mm; 95% CI: (−5.88, −2.09 mm), $p < 0.0001$] (Figure 4). There was substantial heterogeneity, likely due to the smaller number of studies included in this analysis.

3.4 | HFHs

The evaluation of HFHs, conducted across five studies involving 1,239 patients, revealed that LBBAP was associated with a significantly lower risk of hospitalizations due to heart failure compared to RVP [OR = 0.26; 95% CI: (0.16, 0.44), $p < 0.0001$]

Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Li et al. 2021	6	246	13	120	27.4%	0.21 [0.08, 0.56]
liu X et al 2022	1	32	5	18	5.4%	0.08 [0.01, 0.79]
Niu HX et al 2021	0	20	3	30	3.0%	0.19 [0.01, 3.92]
Sharma et al. 2021	12	321	40	382	61.4%	0.33 [0.17, 0.64]
Zhang et al. 2021	0	33	2	37	2.9%	0.21 [0.01, 4.58]
Total (95% CI)		**652**		**587**	**100.0%**	**0.26 [0.16, 0.44]**
Total events	19		63			

Heterogeneity: Tau² = 0.00; Chi² = 1.77, df = 4 (P = 0.78); I² = 0%
Test for overall effect: Z = 5.04 (P < 0.00001)

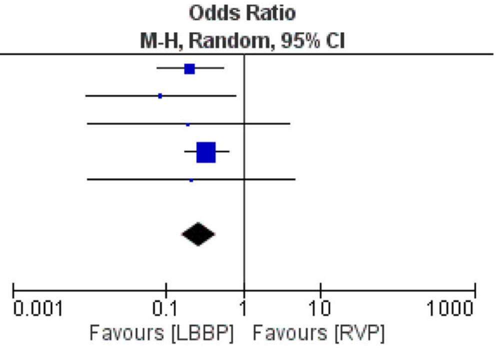

FIGURE 5 | Forest plot representing heart failure hospitalization.

Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Li et al. 2021	235	248	120	120	20.9%	0.07 [0.00, 1.23]
Niu HX et al 2021	20	21	30	30	16.7%	0.22 [0.01, 5.77]
Ondiviela et al. 2021	57	60	57	60	42.9%	1.00 [0.19, 5.16]
Zhang et al. 2021	29	33	37	37	19.4%	0.09 [0.00, 1.69]
Total (95% CI)		**362**		**247**	**100.0%**	**0.28 [0.06, 1.22]**
Total events	341		244			

Heterogeneity: Tau² = 0.61; Chi² = 4.06, df = 3 (P = 0.25); I² = 26%
Test for overall effect: Z = 1.70 (P = 0.09)

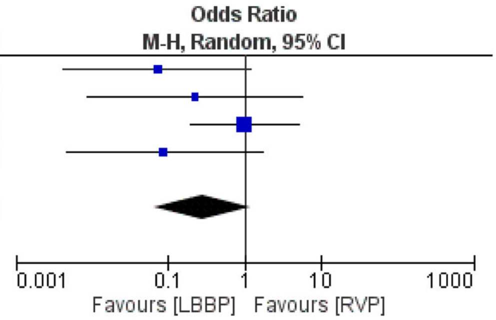

FIGURE 6 | Forest plot representing Implant success rate.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
1.3.1 At the time of implantation								
Chen X et al 2020	532.61	95.11	237	520.87	88.43	317	7.4%	11.74 [-3.80, 27.28]
Das et al 2020	703.27	31.54	22	681.82	42.2	28	7.2%	21.45 [1.00, 41.90]
Li et al. 2021	818.83	165.73	33	844.29	182.95	37	3.5%	-25.46 [-107.14, 56.22]
liu X et al 2022	830.61	120.6	33	817.14	104.98	21	4.6%	13.47 [-47.43, 74.37]
Miyajima et al. 2022	644	114	39	614	128	42	5.2%	30.00 [-22.71, 82.71]
Niu HX et al 2021	696.2	124.7	20	686.3	110.8	30	4.3%	9.90 [-57.62, 77.42]
Wang et al. 2019	676.07	122.29	61	664.15	103.73	65	6.0%	11.92 [-27.80, 51.64]
Zhang et al. 2021	757.2	164	246	853.6	258.5	120	5.3%	-96.40 [-146.99, -45.81]
Zhu et al 2021	783	154	376	782	217	313	6.8%	1.00 [-27.64, 29.64]
Subtotal (95% CI)			**1067**			**973**	**50.4%**	**2.11 [-17.27, 21.49]**
Heterogeneity: Tau² = 428.36; Chi² = 19.85, df = 8 (P = 0.01); I² = 60%								
Test for overall effect: Z = 0.21 (P = 0.83)								
1.3.2 At Follow-up								
Chen K et al. 2019	870.75	146.69	20	950.6	168.78	20	2.8%	-79.85 [-177.85, 18.15]
Chen X et al 2020	455.28	64.65	237	495.18	62.5	315	7.6%	-39.90 [-50.64, -29.16]
Das et al 2020	714.55	137.09	22	710.41	69.4	28	4.5%	4.14 [-58.65, 66.93]
Li et al. 2021	621.3	149	246	771.2	184.4	120	6.2%	-149.90 [-187.78, -112.02]
liu X et al 2022	583.59	69.87	33	548.17	89.27	21	5.7%	35.42 [-9.59, 80.43]
Miyajima et al. 2022	536	71	39	534	92	42	6.3%	2.00 [-33.65, 37.65]
Niu HX et al 2021	507.6	72.3	20	521	78.2	30	5.9%	-13.40 [-55.67, 28.87]
Wang et al. 2019	478.23	71.66	58	488.12	83.69	64	6.8%	-9.89 [-37.47, 17.69]
Zhang et al. 2021	826.27	164.45	33	856.7	160.73	37	3.8%	-30.43 [-106.79, 45.93]
Subtotal (95% CI)			**708**			**677**	**49.6%**	**-29.92 [-61.88, 2.05]**
Heterogeneity: Tau² = 1785.02; Chi² = 56.16, df = 8 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 1.83 (P = 0.07)								
Total (95% CI)			**1775**			**1650**	**100.0%**	**-15.03 [-35.74, 5.67]**

Heterogeneity: Tau² = 1436.47; Chi² = 117.86, df = 17 (P < 0.00001); I² = 86%
Test for overall effect: Z = 1.42 (P = 0.15)
Test for subgroup differences: Chi² = 2.82, df = 1 (P = 0.09), I² = 64.5%

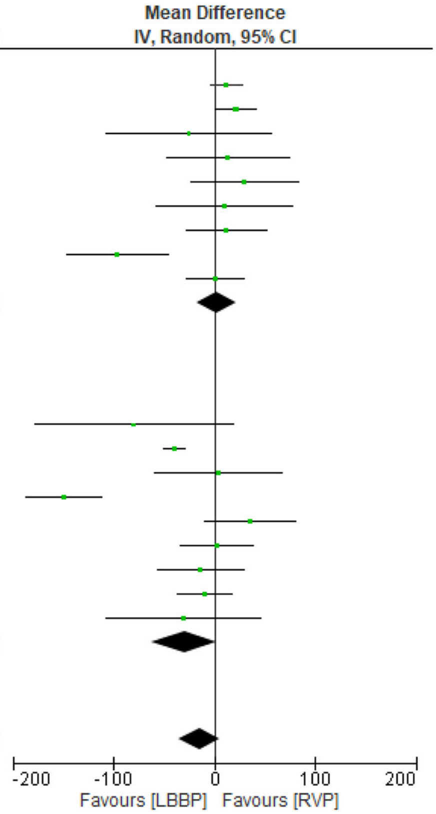

FIGURE 7 | Forest plot representing pacing impedance.

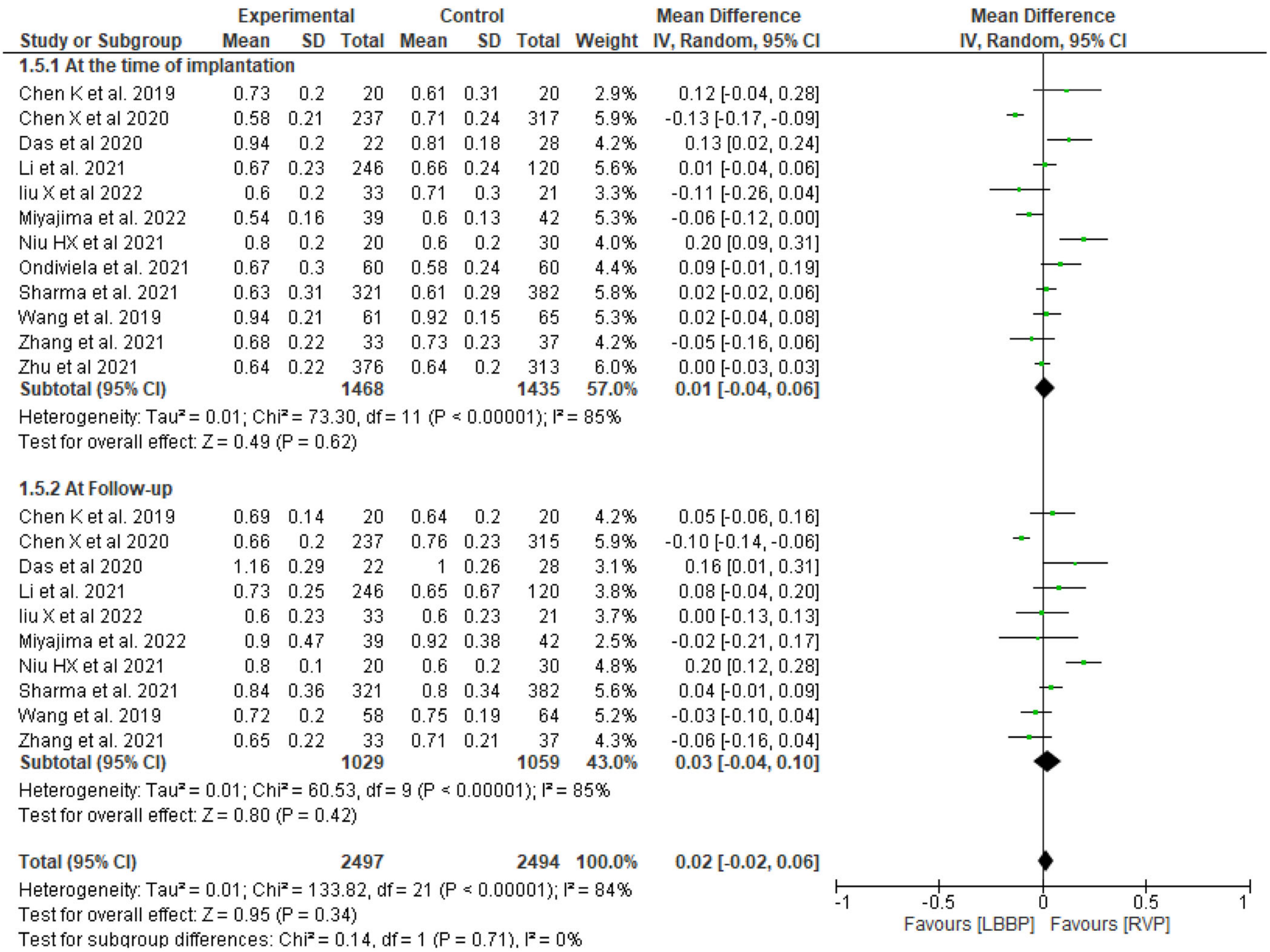

FIGURE 8 | Forest plot representing pacing threshold.

(Figure 5). Notably, the analysis exhibited no heterogeneity among the included studies.

3.5 | Implant Success Rate

An evaluation of four studies aimed to discern the comparative success rates of implanting either LBBAP or RVP into the myocardium, involving a cohort of 609 patients. The results indicated that the success rates exhibited no significant preference for either intervention [RR = 0.28; 95% CI: (0.06, 1.22), $p = 0.09$]. Notably, Li et al. [11] contributed significantly to this finding, accounting for two-thirds of the overall weight in the analysis, as illustrated in Figure 6. Overall, heterogeneity observed was below 50%, rendering it insignificant.

3.6 | Pacing Impedance

For the assessment of pacing impedance, nine studies were incorporated to examine impedance at the time of implantation, involving 2040 patients, and nine studies were included for impedance evaluation at follow-up, encompassing 1,385 patients. At the time of implantation, no significant difference emerged between LBBAP and RVP groups [MD = 2.11 Ω; 95% CI: (−17.27, 21.49), $p = 0.83$]. Similarly, no significant disparity was noted at follow-up [MD = −29.29 Ω; 95% CI: (−61.88, 2.05), $p = 0.07$].

The overall analysis revealed a similar trend, as no significant decrease in impedance was encountered in LBBAP patients [MD = −15.03 ms; 95% CI: (−35.74, 5.67), $p = 0.15$] (Figure 7). A heterogeneity analysis was conducted to enhance the precision of our findings. No reduction in heterogeneity was achieved.

3.7 | Pacing Threshold

The examination of pacing thresholds involved 12 studies, encompassing 2903 patients at the time of implantation, and 10 studies with 2088 patients during follow-up. The analysis revealed no significant correlation between either pacing intervention, with no discernible advantage for any patient group at either time point [MD = 0.02 V; 95% CI: (−0.02, 0.06), $p = 0.36$] (Figure 8). The analysis revealed significant heterogeneity among studies. Sensitivity analysis was performed, but no fruitful results were seen.

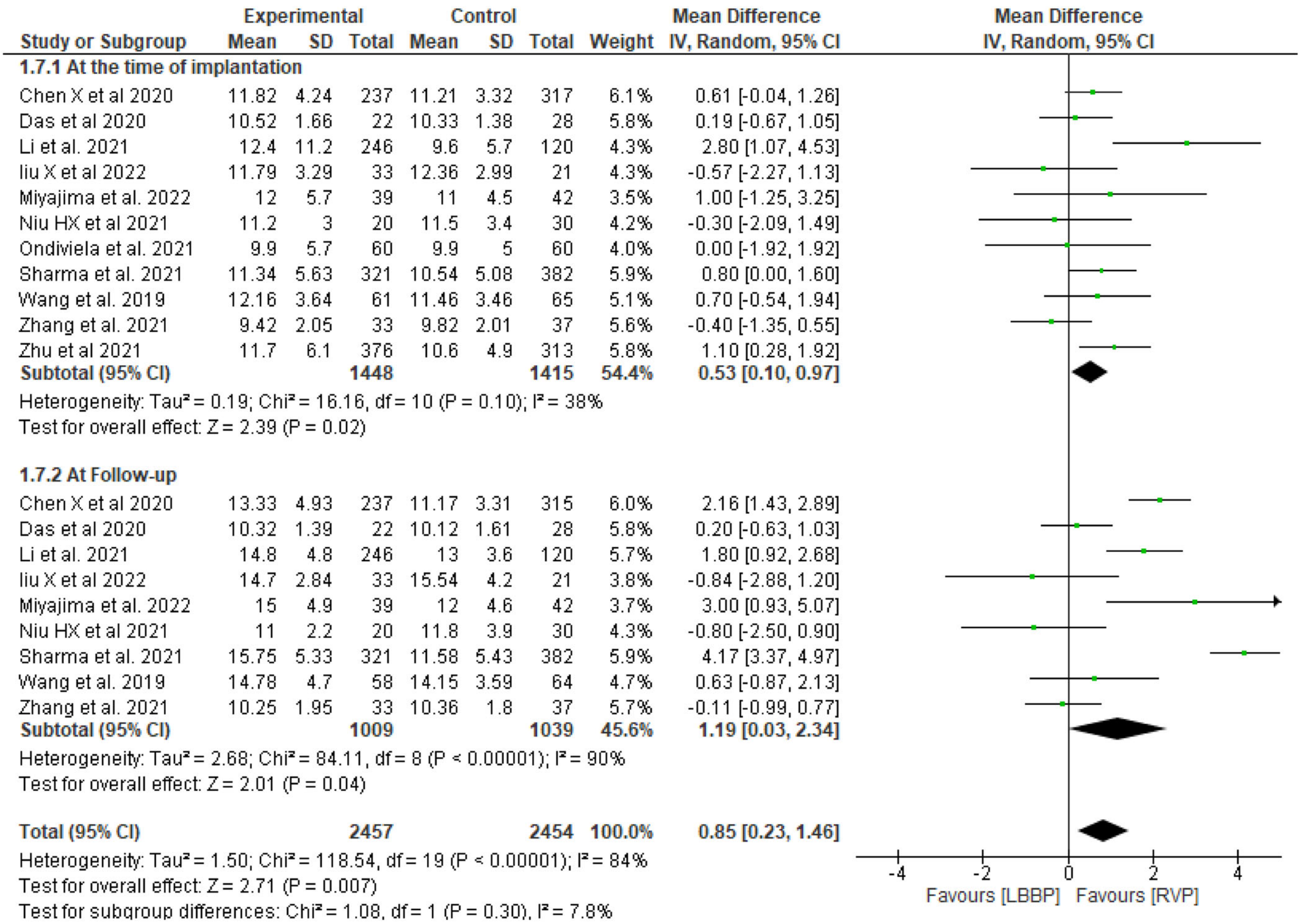

FIGURE 9 | Forest plot representing R-wave amplitude.

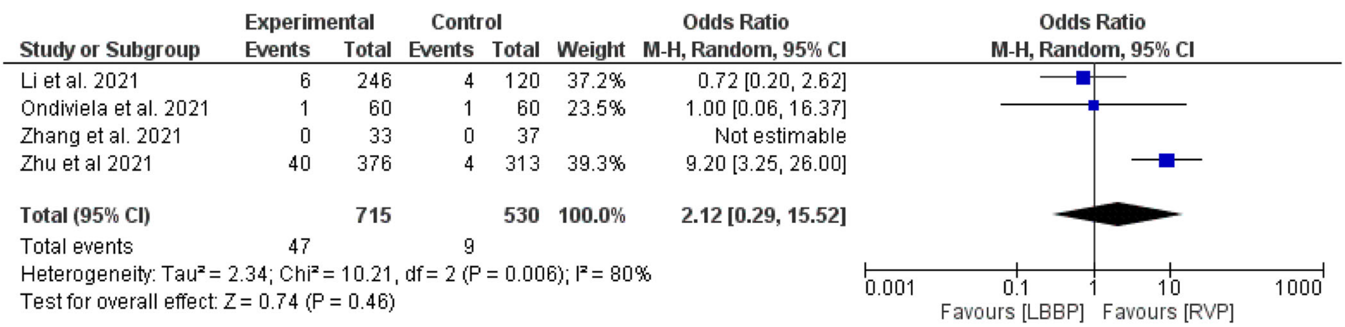

FIGURE 10 | Forest plot representing risk of complications.

3.8 | R-Wave Amplitude

The assessment of R-wave amplitudes at implantation included data from 11 studies (2863 patients), while follow-up data came from nine studies (2048 patients). A significant difference in R-wave amplitudes was found between the LBBAP and RVP groups, with the RVP group showing higher values [MD = 0.85; 95% CI: (0.23, 1.46), $p = 0.007$] (Figure 9). Substantial heterogeneity was noted across the studies, potentially due to differences in study design or patient characteristics.

3.9 | Complications

The analysis of complications included data from four studies, encompassing a total of 1245 patients. The results showed no significant difference in the incidence of complications between the LBBAP and RVP groups [OR = 2.12; 95% CI: (0.29, 15.52), $p = 0.46$] (Figure 10). However, considerable heterogeneity was detected, with the study by Zhu et al. contributing substantially to this variation [24].

3.10 | Quality Assessment

A quality assessment was conducted for the observational studies and RCTs employing the Newcastle–Ottawa Scale and the Cochrane Risk of Bias 2.0 tool, respectively.

All included studies demonstrated a high level of methodological rigor and quality. The evaluation results are summarized in Supporting Information S1: Table 1, providing a snapshot of each study's strengths and potential limitations. Additionally, Supporting Information S1: Figure 2 visually represents the key findings of the quality assessment of RCTs, offering a clear and concise overview of the methodological integrity and potential biases identified across the included studies. The visual inspection of funnel plot (Supporting Information S1: Figure 3) showed no risk of publication bias.

4 | Discussion

Our meta-analysis included 14 studies (10 observational and four RCTs) involving 3062 patients with atrioventricular block (AVB). Over an average follow-up of 12 months, LBBAP demonstrated significant advantages over RVP in key outcomes, such as reduced QRS duration, smaller LVEDD, and improved left ventricular ejection fraction (LVEF).

AVB, affecting around 0.5% of the population, is a common indication for cardiac pacing [25]. RVP has been the conventional approach, but concerns about its adverse effects, such as ventricular dyssynchrony, impaired ventricular function, heart failure, atrial fibrillation, and increased mortality, have emerged [26, 27]. These issues have driven interest in alternative pacing strategies that better preserve ventricular function.

His bundle pacing (HBP), which uses the heart's native conduction system, can prevent dyssynchrony and improve outcomes but is technically challenging and not suitable for all patients. Further research is needed to compare HBP with other pacing methods and to identify the ideal candidates for HBP [28].

LBBAP, a newer technique targeting the left bundle branch area, aims to replicate natural conduction and avoid dyssynchrony [29]. Studies suggest that LBBAP reduces QRS duration, improves ventricular function, and enhances clinical outcomes, particularly in heart failure patients with reduced ejection fraction [30]. However, data on LBBAP's efficacy in AVB patients with pEF are limited. Our meta-analysis is the first to systematically assess LBBAP in this population.

Our findings support the superiority of LBBAP over RVP in reducing QRS duration and LVEDD, increasing LVEF, and improving R-wave amplitude. These improvements suggest that LBBAP promotes better ventricular synchronization and may prevent or reverse ventricular remodeling in patients with AVB and pEF. Heterogeneity in QRS duration and LVEDD may be due to varying follow-up periods across studies.

Previous studies align with our results. Li et al. showed that LBBAP reduced HFHs and the need for biventricular pacing upgrades in patients with AVB and pEF. Ye et al. demonstrated that LBBAP improved left ventricular function and reversed pacing-induced cardiomyopathy in patients with infranodal AVB and reduced ejection fraction [31]. Zhang et al.'s network meta-analysis found that both LBBAP and HBP outperformed RVP in reducing QRS duration and preserving LVEF in AVB patients [32].

However, outcomes such as implantation success rates, complication risks, pacing impedance, and thresholds did not significantly differ between LBBAP and RVP. The limitations of this analysis include the small number of randomized trials and small study populations, particularly regarding adverse events. Future large-scale, well-designed trials are needed to validate these findings. Additionally, the included studies had moderate to low quality, with potential risks of bias and confounding, warranting cautious interpretation of the results.

5 | Conclusion

Our analysis shows that LBBAP is superior to RVP in reducing QRS duration, LVEDD, and increasing left ventricular ejection fraction. These findings suggest that LBBAP offers better ventricular synchronization and may prevent ventricular remodeling. Additionally, we observed a significant increase in R-wave amplitude in the RVP group. However, no significant differences were found in implant success rates, complication risks, pacing impedance, or pacing threshold between LBBAP and RVP. The study's limitations, including heterogeneity in the results, highlight the need for more rigorous, well-designed trials to confirm our findings and assess the long-term effects of LBBAP in patients with AVB and pEF.

Author Contributions

Irfan Ahsan: conceptualization, project administration, resources. **Hussam Al Hennawi:** conceptualization, investigation, methodology, project administration. **Angad Bedi:** conceptualization, methodology, project administration. **Muhammad Khuzzaim Khan:** conceptualization, project administration, resources, writing– original draft. **Nikhil Duseja:** methodology, resources, writing–original draft. **Reginald T. Ho:** conceptualization, investigation, methodology, project administration.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Publicly available data was used.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.