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ORIGINAL ARTICLE

Conduction system pacing vs. biventricular pacing in patients with ventricular dysfunction and AV block

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Abstract

Background: It is unknown whether His-Purkinje conduction system pacing (HPCSP), as either His bundle or left bundle branch pacing, could be an alternative to cardiac resynchronization therapy (BiVCRT) for patients with left ventricular dysfunction needing ventricular pacing due to atrioventricular block. The aim of the study is to compare the echocardiographic response and clinical improvement between HPCSP and BiVCRT.

Methods: Consecutive patients who successfully received HPCSP were compared with a historical cohort of BiVCRT patients. Patients were 1:1 matched by age, LVEF, atrial fibrillation, renal function and cardiomyopathy type. Responders were defined as patients who survived, did not require heart transplantation and increased LVEF ≥5 points at 6-month follow-up.

Results: HPCSP was successfully achieved in 92.5% (25/27) of patients. During follow-up, 8% (2/25) of HPCSP patients died and 4% (1/25) received a heart transplant, whereas 4% (1/25) of those in the BiVCRT cohort died. LVEF improvement was 10% ± 8% HPCSP versus 7% ± 5% BiVCRT ($p = .24$), and the percentage of responders was 76% (19/25) HPCSP versus 64% (16/25) BiVCRT ($p = .33$). Among survivors, the percentage of patients who improved from baseline II–IV mitral regurgitation (MR) to 0–I MR was 9/11 (82%) versus 2/8 (25%) ($p = .02$). Compared to those with BiVCRT,

Abbreviation: AF, atrial fibrillation; AV, atrioventricular; BiV, biventricular; bpm, beats per minute; CRT, cardiac resynchronization therapy; HBP, His bundle pacing; HPCSP, His-Purkinje conduction system pacing; ICD, implantable cardioverter-defibrillator; LBBB, left bundle branch block; LBBP, left bundle branch pacing; LV, left ventricular; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; ms, milliseconds; RV, right ventricular; VV, interventricular.

patients with HPCSP achieved better NYHA improvement: 1 point versus 0.5 (OR 0.34; $p = .02$).

Conclusion: HPCSP in patients with LVEF ≤45% and atrioventricular block improved the LVEF and induced a response similar to that of BiVCRT. HPCSP significantly improved MR and NYHA functional class. HPCSP may be an alternative to BiVCRT in these patients. (Figure 1. Central Illustration).

KEYWORDS
AV block, cardiac resynchronization therapy, His-Purkinje conduction system pacing, left ventricular dysfunction, mitral regurgitation

1 | INTRODUCTION

In multiple trials, cardiac resynchronization therapy (CRT) has shown its value in improving cardiac function, reversing ventricular remodeling, improving NYHA functional class, reducing heart failure hospitalizations and increasing survival. It is the cornerstone therapy—endorsed by current guidelines[1] for patients with heart failure, reduced left ventricular (LV) ejection fraction (LVEF) and wide QRS complex or indication for pacing.

Previously published studies have clearly shown that chronic right ventricular (RV) pacing might have deleterious effects on cardiac structure and function.[2,3] Continuous RV pacing may lead to progressive LV dysfunction and heart failure, especially in patients with preexisting cardiomyopathy or reduced LVEF. Small randomized trials and registries suggested that patients with moderate-to-severe LV dysfunction might benefit from an implant for biventricular cardiac resynchronization therapy (BiVCRT) instead of conventional RV pacing.[3–6] BiVCRT may prevent the deleterious effect of chronic RV apical pacing in these patients by correcting the electrical and mechanical asynchrony induced with RV pacing.[1] Approximately 10% of patients with indications for BiVCRT have LV dysfunction and the need for either de novo continuous ventricular pacing or an upgrade from a previous conventional pacemaker with RV pacing.[7]

His Purkinje conduction system pacing (HPCSP), either by his bundle pacing (HBP)[8] or left bundle branch pacing (LBBP)[9] activates the LV through the intrinsic conduction system (physiological activation), thus decreasing the electrical and mechanical asynchrony induced by RV pacing. Therefore, HPCSP may be a good alternative to conventional BiVCRT in patients with LV dysfunction and the need for continuous ventricular pacing due to atrioventricular (AV) block.

It is currently unknown whether HPCSP could be a valid alternative to conventional CRT in patients with LV dysfunction and AV block. Previously published studies have shown encouraging results regarding HPCSP as an alternative to BiVCRT.[8,10] However, these studies form a heterogeneous population, with few patients needing pacing due to AV block or previous RV pacing, and include patients with mild or slight LV dysfunction (LVEF < 50%).

Therefore, our study aimed to compare the echocardiographic response and clinical improvement at the midterm follow-up (6 months) between HPCSP (either HBP or LBBP) and BiVCRT in patients with indications for permanent pacing (AV block) and LVEF dysfunction. We aimed to address a gap in the knowledge of a subgroup of patients thus far treated with BiVCRT who could also benefit from physiological pacing with HPCSP.

2 | METHODS

2.1 | Study population

This is an observational study comparing a cohort of patients with LV dysfunction (LVEF ≤ 45%) who successfully received HPCSP due to AV block (between January 2019 and September 2020) with a previously published historical cohort of patients who successfully received BiVCRT due to AV block and the need for continuous ventricular pacing (2006–2014).[11] Patients were 1:1 matched by baseline LVEF (tolerance range ± 5 points), type of cardiomyopathy (ischemic/nonischemic), rhythm (sinus/permanent atrial fibrillation), age (tolerance range ± 5 years), and renal function (same Kidney Disease Improving Global Outcomes [KDIGO-stage]). All patients had complete clinical (15 days, 45 days, and 6 months) and echocardiographic (baseline and 6 months) follow-up. During the clinical follow-up, the NYHA functional class of the patients was assessed.

The study protocol was approved by the Ethics Committee at our institution, and written informed consent was obtained from all patients.

2.2 | Device implantation

In the conduction pacing cohort, a SelectSecure 3830 pacing lead (Medtronic®, Minneapolis, MN, USA), delivered via a fixed-curve C315-His sheath, was used in all cases. HBP was the first approach in all patients (Figure 2A); if HBP could not be performed (high pacing thresholds (>2.75V/1 ms), no His signal, or inability to correct left bundle branch block morphology), LBBP was attempted (Figure 2B). The location for LBBP was 1—1.5 cm distal to the His signal. At this site, the unipolar paced QRS morphology before fixation showed a "W" pattern in V1. The sheath was rotated counterclockwise to maintain the lead tip perpendicular to the septum. The pacing lead was rapidly rotated

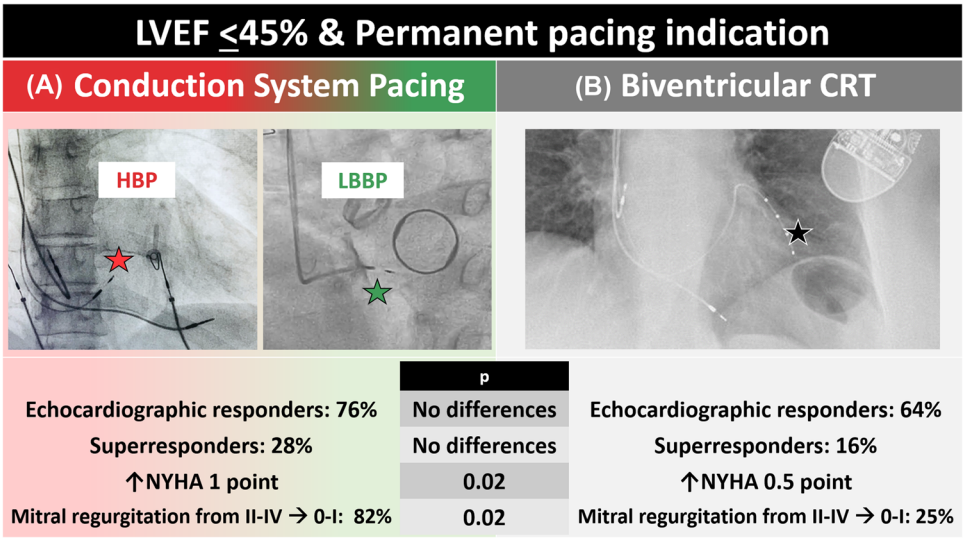

FIGURE 1 Central illustration. Two therapeutic approaches in patients with ventricular dysfunction (LVEF ≤ 45%) and indication for pacing due to AV block: His Purkinje conduction system pacing (A) and biventricular CRT (B). HPCSP with either HBP or LBBP in patients with LVEF ≤45% dysfunction and a ventricular pacing indication showed an echocardiographic response at the 6-month follow-up comparable to that of biventricular CRT. Abbreviations: CRT, cardiac resynchronization therapy; HBP, His bundle pacing; LBBP, left bundle branch pacing [Color figure can be viewed at wileyonlinelibrary.com]

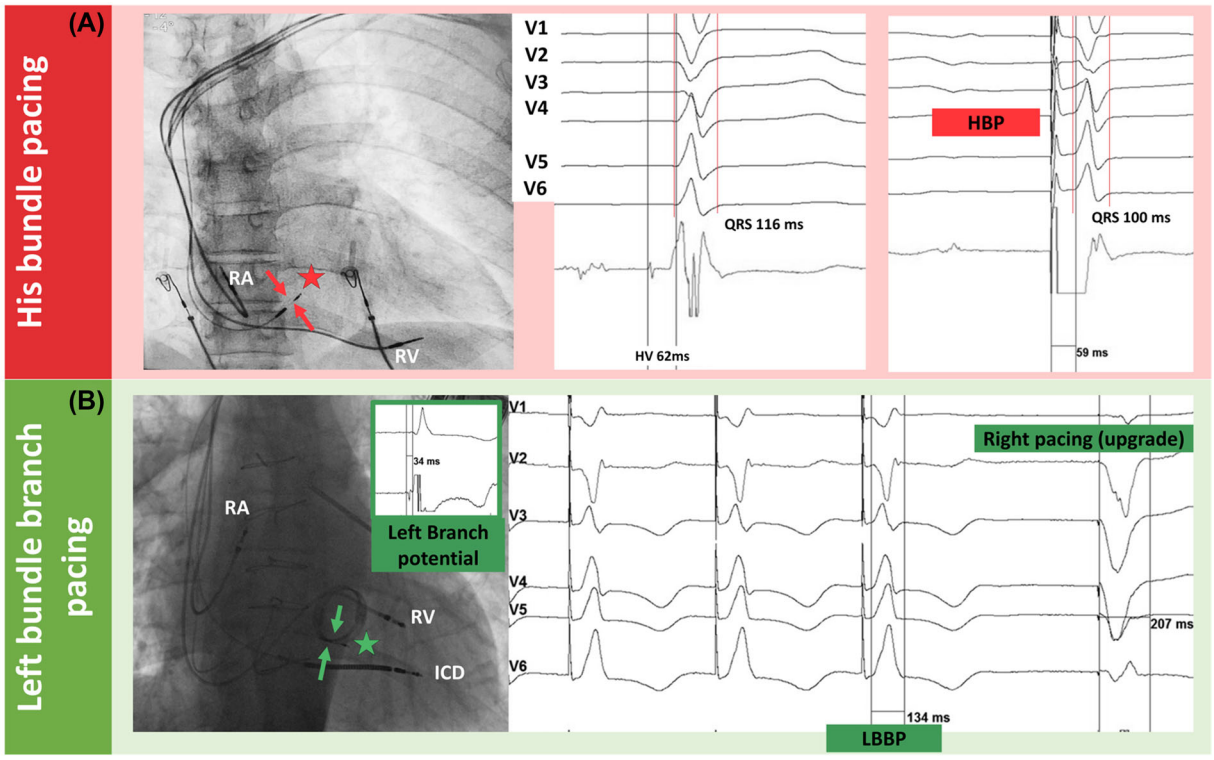

FIGURE 2 His Purkinje conduction system pacing strategies: (A) His bundle pacing (HBP): X-ray shows the lead implanted in the His area (red arrows and red star). Baseline ECG with narrow QRS (116 ms) in a patient with paroxysmal 2:1 and complete AV block (not shown) with LVEF 40%. Selective HBP pacing obtained the same QRS morphology (100 ms). (B) Left bundle branch pacing (LBBP) in a patient with a previous bicameral pacemaker that was upgraded due to left ventricular dysfunction. X-ray shows the lead implanted in the left bundle branch (green arrows, green star). The baseline QRS with right ventricular (RV) pacing was 207 ms; LBBP obtained a QRS of 134 ms, qR in V1 and left bundle branch potential at 34 ms (detail of the figure, green square). Abbreviations: HBP, His bundle pacing; ICD, implantable cardioverter-defibrillator; LBBP, left bundle branch pacing; RA, right atrium; RV, right ventricle [Color figure can be viewed at wileyonlinelibrary.com]

clockwise, controlling impedance. Unipolar pacing showed right bundle branch block and LBBP was confirmed according to published criteria.[12] For patients who received an implantable cardioverter-defibrillator (ICD) or who received a ventricular lead as back-up, the RV lead was placed at the RV apex or septum. Conventional atrial leads were used in patients in sinus rhythm or with paroxysmal atrial fibrillation (AF).

In the BiVCRT cohort, a LV lead was implanted according to standard clinical practice. The LV electrode was inserted through the coronary sinus into a lateral vein whenever possible.

In both groups, patients in sinus rhythm were programmed in DDD mode or DDDR in the case of sick sinus syndrome; the minimum heart rate was 50 bpm. Patients with AF were programmed in VVIR mode at 70–75 bpm, with the maximum heart rate set at 85% of the maximum theoretical heart rate.

2.3 | Echocardiographic evaluation

Standard Doppler echocardiography was performed at baseline (with RV pacing) and at the 6-month follow-up using a commercially available system (Vivid E95, GE-Vingmed, Milwaukee, WI, USA). LVEF was calculated (baseline and 6-month follow-up) by the Simpson rule from two- and four-chamber apical views. Echocardiographic response (primary endpoint) was defined as patient survival without a requirement for heart transplantation and with an increase in LVEF of ≥5 points at the 6-month follow-up. Mitral regurgitation (MR) was qualitatively evaluated at baseline and at the 6-month follow-up following current recommendations. Patients were considered superresponders if they presented ≥50% LVEF and functional recovery or an increase in LVEF of ≥20 points at the 6-month follow-up.

2.4 | Electrocardiographic measurements

ECG measurements were obtained with RV pacing (baseline) and after device implantation with the final programming in the Electrophysiology Laboratory at a screen speed of 300 mm/s by two experienced researchers who measured all the ECGs. QRS measurements were performed using computerized recordings that were digitally stored (EP-TRACER, CardioTek). QRS onset was considered to be the start of fast deflection. "Delta QRS" was calculated as QRS with final programming (BiVCRT or HPCSP) minus QRS with RV pacing.

2.5 | Statistical analysis

Continuous data were presented as the mean ± SD. Qualitative variables are expressed as the number of cases and proportions. Baseline characteristics were analyzed with the χ^2 test (categorical variables) or Student's *t*-test for paired data (continuous variables).

The primary endpoint was response at the 6-month follow-up, defined as patient survival, no requirement for heart transplantation and an increase in LVEF of ≥5 points. The primary endpoint and all the other outcomes that were assessed in the two matched cohorts were analyzed with conditional logistic regression. Statistical analysis was performed using R version 4.1.0 software (R Project for Statistical Computing).

3 | RESULTS

HPCSP was successfully implanted in 25 (92.6%) of 27 consecutive patients with LVEF dysfunction and AV block. The cohort of 25 patients who successfully received HPCSP was compared with a historical cohort of 25 patients who received BiVCRT due to AV block and the need for continuous ventricular pacing. The baseline clinical and echocardiographic characteristics of both groups are shown in Table 1. The percentage of patients who received an ICD instead of a pacemaker was similar between the two groups: 9/25 (36%) HPCSP versus 11/25 (44%) BiVCRT ($p = .57$).

3.1 | Conduction system pacing

Of the 25 patients with successful HPCSP, 18/25 (72%) received HBP, and 7/25 (28%) received LBBP. LBBP was performed in all cases after failure of HBP for the following reasons: no LBBB correction in three patients and inability to reach the his bundle in four patients. The mean total time of the system implant procedure was 102 ± 32 min with HPCSP, and the fluoroscopy time was 19 ± 9 min.

Pacing thresholds at implantation were lower in patients with LBBP than in those with HBP, 0.8 ± 0.3 V (0.4 ms) versus 1.7 ± 1.0 V (1 ms) ($p = .03$; 95% CI 0.08, 1.70). Pacing thresholds remained stable at the 6-month follow-up, and LBBP thresholds remained lower than those of HBP: 0.6 ± 0.2 V (0.4 ms) versus 1.1 ± 0.7 V (1 ms). Among patients who received pacemakers instead of ICDs (16/25, 64%), implantation of an RV lead as back-up was performed in 13/16 (81%).

3.2 | Paced QRS shortening with HPCSP versus biventricular CRT

The baseline QRS was 178 ± 21 ms and 173 ± 32 ms in the HPCSP cohort and BiVCRT cohort, respectively ($p = .54$). After implantation, the paced QRS was 121 ± 20 ms and 147 ± 17 ms with HPCSP and BiVCRT, respectively ($p < .001$). HPCSP showed greater shortening of the QRS (54 ± 26 ms) than BiVCRT (32 ± 30 ms) ($p = 0.02$; 95% CI 3.4, 40.2).

3.3 | Follow-up at 6 months

At the 6-month follow-up, the % ventricular pacing was 97% ± 5% in the HPCSP group and 98% ± 3% in the BiVCRT cohort ($p = .29$). During the 6-month follow-up, 1/25 (4%) patients from the HPCSP group

TABLE 1 Baseline characteristics of HPCSP and biventricular cardiac resynchronization therapy cohorts

	His-Purkinje conduction system pacing ($n = 25$)	Biventricular CRT ($n = 25$)	p
Age (years)	72 ± 9	69 ± 8	.22
Sex (males)	68% (17)	76% (19)	.53
Ischemia	32% (8)	32% (8)	1
Upgrade from RV pacing	44% (11)	60% (15)	.26
Glomerular filtration rate (ml/min)	65 ± 20	68 ± 23	.73
NYHA class	2.8 ± 1	2.8 ± 0.6	1
NYHA I–II	36% (9)	28% (7)	.54
NYHA III–IV	64% (16)	72% (18)	
Permanent AF	16% (4)	16% (4)	1
LVEDD (mm)	57 ± 8	62 ± 9	.02
LVESD (mm)	41 ± 9	48 ± 10	.01
LVEF	32 ± 7%	30 ± 6%	.41
Left atrium (antero-posterior diameter)	44 ± 9	47 ± 8	.20
Grade of mitral regurgitation			.27
0	16% (4)	16% (4)	
I	32% (8)	52% (13)	
II	36% (9)	24% (6)	
III	4% (1)	8% (2)	
IV	12% (3)	0% (0)	
QRS width (ms)	178 ± 21 ms	173 ± 32 ms	.54

received a heart transplant, and 2/25 (8%) died: one noncardiac death (disseminated cancer) and one cardiac death (myocardial infarction and refractory cardiogenic shock in a patient with nonrevascularizable severe ischemic cardiomyopathy). In the BiVCRT cohort, 1/25 (4%) patients died due to a noncardiac etiology ($p = .30$).

In relation to postintervention complications, there were two patients—one with HPCSP and the other with BiVCRT—who required reintervention (<24 h) due to loss of capture because of lead displacement (HBP lead and coronary sinus lead, respectively). One case of pericardial effusion at the 15-day follow-up in a patient from the HPCSP cohort was resolved with anti-inflammatory treatment and did not require drainage.

3.4 | Echocardiographic follow-up

At 6 months, a significant increase in the LVEF was observed in the survivors of both groups. In the HPCSP cohort ($n = 22$), LVEF improved from 32% ± 7% to 43% ± 10% ($p < .001$), whereas in the BiVCRT cohort ($n = 24$), LVEF improved from 30% ± 6% to 37% ± 9% ($p < .001$) (Figure 3, Table 2). Improvement in LVEF (delta LVEF) was not significantly different between HPCSP versus BiVCRT: 10 ± 8% versus 7% ± 5%, respectively ($p = .24$; OR 0.94, 95% IC 0.86, 1.04) (Table 2).

The percentages of responders and superresponders were similar between the two groups: 19/25 (76%) HPCSP versus 16/25 (64%) BiVCRT ($p = .33$, OR 0.50, 95% CI 0.13, 2.00) and 7/25 (28%) HPCSP versus 4/25 (16%) BiVCRT ($p = .31$; OR 0.49, 95% CI 0.12, 1.95).

The evolution of mitral regurgitation among survivors is shown in Figure 4. The percentage of patients who improved from baseline II–IV MR to 0–I MR was 9/11 (82%) with HPCSP versus 2/8 (25%) with BiVCRT ($p = .02$).

3.5 | NYHA class improvement

At the 6-month follow-up, a significant improvement in the NYHA class was observed in survivors of both groups: the NYHA class improved from 2.6 to 1.6 in the HPCSP group ($p < .001$) and from 2.8 to 2.3 in the BiVCRT group ($p = .005$). Improvement in the NYHA class was greater in the HPCSP group than in the BiVCRT group, 1 point versus 0.5 points (OR 0.34; 95% CI 1.01, 8.49; $p = .02$).

Among survivors, the percentage of patients with advanced heart failure (NYHA III–IV) decreased from 13/22 (59%) to 2/22 (9%) in the HPCSP group and from 17/24 (71%) to 9/24 (24%) in the BiVCRT group ($p = 0.02$; OR 0.17, 95% CI 0.03, 0.88) (Figure 5).

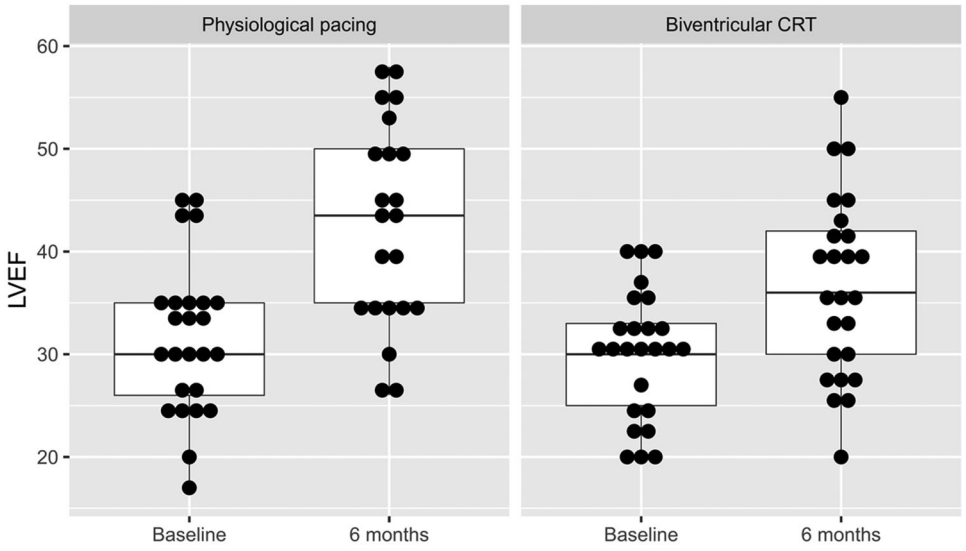

FIGURE 3 Change in left ventricular ejection fraction (LVEF) between baseline and 6-month follow-up with physiological pacing and biventricular CRT

TABLE 2 Outcome measures at the 6-month follow-up according to the type of pacing

	Physiological pacing($n = 25$; 3 patients dead, considered nonresponders)	Biventricular CRT($n = 25$; 1 patient dead, considered a nonresponder)	*p*
LVEF (%)	43% ± 10%	37% ± 9%	.07
Delta LVEF (%)	10% ± 8%	7% ± 5%	.24
LVEF responders (≥5%) (%)	76%	64%	.33
Superresponders* (%)	28%	16%	.31
Mitral regurgitation	59% (13/22 alive)	71% (17/24 alive)	.42
0	40.9% (9)	29.2% (7)	
I	45.5% (10)	45.8% (11)	
II	9.1% (2)	12.5% (3)	
III	4.5% (1)	8.3% (2)	
IV	0% (0)	4.2% (1)	
NYHA functional class (improvement points)	1	0.5	.02
Mild heart failure NYHA I–II	90.9% (20/22)	62.5% (15/24)	.024
Advanced heart failure NYHA III–IV	9.1% (2/22)	37.5% (9/24)	

*Superresponders: ≥50% LVEF and functional recovery or increase in LVEF of ≥20 points at the 6-month follow-up.

3.5.1 | Comparison between HPCSP modes (HBP vs. LBBP)

At 6 months, there was no difference in the improvement of LVEF between patients treated with HBP and those treated with LBBP: 11% ± 9% versus 7% ± 5% ($p = .33$). The percentages of clinical (1-point improvement NYHA) and echocardiographic responders between HBP and LBBP were also similar: 10/18 (55%) versus 3/7 (43%) ($p = .57$) and 14/18 (78%) versus 5/7 (71%) ($p = .74$), respectively.

3.6 | Follow-up at 12 months

At the 12-month follow-up, there were no additional deaths or cardiac transplants in the HPCSP group (overall, 3/25 patients died or had cardiac transplant), and 7 out of 25 patients (28%) had been admitted because of heart failure. In the BiVCRT cohort, one additional patient

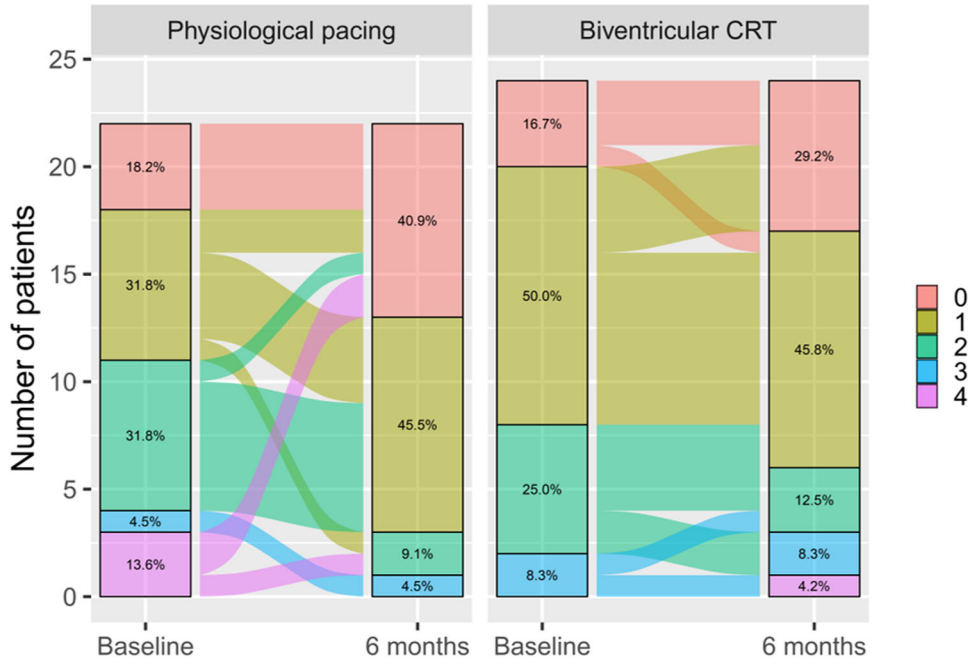

FIGURE 4 Change in mitral regurgitation (MR) among survivors between baseline and 6-month follow-up with physiological pacing and biventricular CRT. 0: no MR; 1: mild MR; 2: moderate MR; 3: moderate-severe MR; 4: severe MR [Color figure can be viewed at wileyonlinelibrary.com]

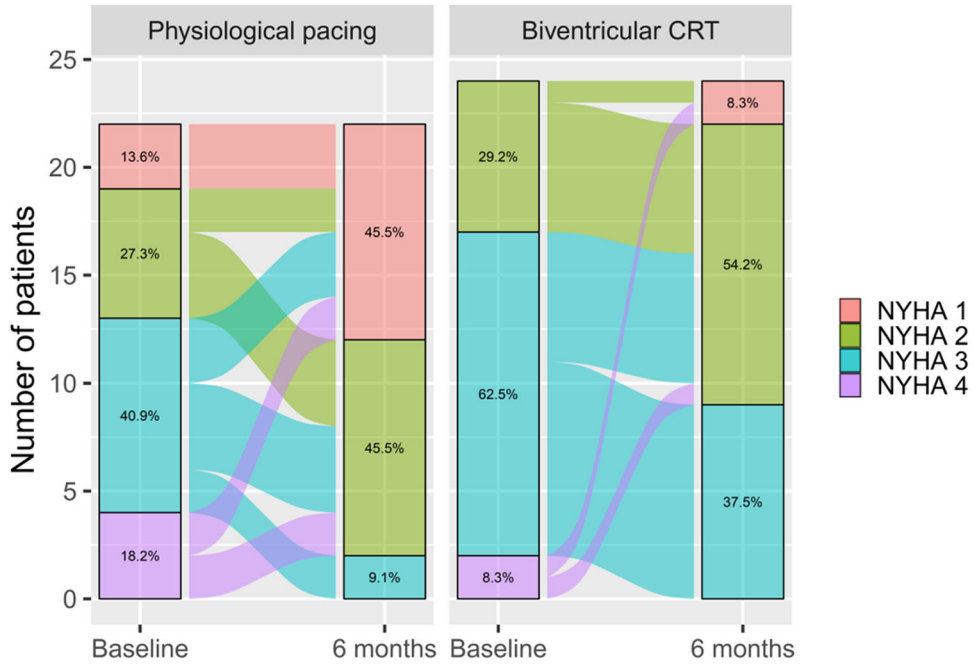

FIGURE 5 Change in NYHA functional class among survivors between baseline and 6-month follow-up with physiological pacing and biventricular CRT [Color figure can be viewed at wileyonlinelibrary.com]

died due to cardiac etiology (overall, 2/25 patients died), and 5 out of 25 patients (20%) required hospitalization for heart failure.

There were no differences in 12-month mortality ($p = 0.64$) nor in heart failure hospitalizations ($p = 0.51$) between HPCSP and BiVCRT cohorts.

4 | DISCUSSION

The main findings of this case-control matched study of patients with permanent pacing indication and LVEF dysfunction are as follows: (1) HPCSP (either with HBP or LBBP) and BiVCRT obtained

similar echocardiographic response and LVEF improvement at the 6-month follow-up; (2) in patients with moderate-severe MR, HPCSP significantly improved the grade of MR compared to BiVCRT; (3) improvement in functional capacity was superior among HPCSP than with BiVCRT; and (4) LBBP implant allowed an increase in the percentage of patients treated successfully with HPCSP with a low rate of complications.

4.1 | Knowledge gap in CRT therapy with conduction system pacing

BiVCRT is the accepted therapy for patients with heart failure with reduced LVEF who have indications for permanent pacing. Current guidelines[1] indicate that HBP could be implemented in patients with AV block and LVEF >40% who are expected to require at least >20% of ventricular pacing. However, the relative merits of HBP and LBBP for maintaining or improving LVEF in patients needing permanent pacing and LV dysfunction are unknown.

To date, conduction system pacing studies have included a wide range of patients with extensive limits of LV dysfunction (LVEF < 50%). However, we have a gap in the knowledge, specifically with regard to patients with moderate or severe ventricular dysfunction and permanent pacing indications. We aimed to study whether HPCSP constitutes an effective alternative to BiVCRT with a similar echocardiographic response.

4.2 | Beneficial effects of HPCSP

Multiple observational studies and three HBP randomized CRT trials[10,13,14] have shown that HPCSP could be an alternative to conventional CRT due to (a) its ability to preserve electrical and LV mechanical synchrony; (b) the feasibility and safety of both strategies (HBP and LBBP)[8,9]; (c) the results of small trials that obtained a similar CRT response,[10,13,14,15] better ventricular resynchronization and greater improvement in hemodynamic parameters with HBP than with BiVCRT[16]; and (d) the promising resynchronization capability of LBBP in patients with LVEF <50%.[17,18] As conventional CRT and HBP, LBBP corrects electrical and mechanical asynchrony, thus decreasing the grade of mitral regurgitation and improving LVEF.

However, the percentage of patients with AV block in studies on HPCSP and CRT indications is low (0%-exclusion criteria,[10] 7.3%,[13] 55%[19]). For this reason, this population was the focus of interest of our study in trying to solve the question of whether HPCSP is a good alternative to BiVCRT in patients with AV block.

4.3 | HPCSP versus biventricular CRT in patients with left ventricular dysfunction (LVEF ≤45%) and pacing indication due to AV block

A recent nonrandomized study by Wu et al[15] with 137 patients with LVEF ≤40% and LBBB who received HBP, LBBP or BiVCRT showed similar improvements in symptoms and LV function with LBBP and HBP; these improvements were significantly greater than those seen in patients with BiVCRT. Unlike our study, the percentage of patients who were treated with HPCSP due to AV block or upgrade from an RV system was only 7/81 (8.6%). On the other hand, Vijayaraman et al[18] described the feasibility and benefits of LBBP in patient candidates for CRT in terms of clinical and echocardiographic improvements in a large multicenter retrospective study of nonconsecutive patients. However, only 14.5% of the total study cohort had LBBP indications due to AV block; moreover, the authors mixed patients with severe or moderate LVEF with those with mild or slightly depressed LVEF (<50%). Our results support the benefits of HPCSP in this specific group of patients with LVEF ≤45% who were candidates for CRT either due to AV block or an upgrade from RV pacing.

Our study showed that the beneficial effects of HPCSP were comparable to those obtained with BiVCRT in terms of LVEF improvement; moreover, HPCSP decreased MR and improved functional class. We highlighted that HPCSP showed greater shortening of the QRS (54 ± 26 ms) than biventricular CRT (32 ± 30 ms), which was a good sign of electrical resynchronization. Prior studies have shown that QRS shortening is associated with improved clinical outcomes. One could speculate that in patients with baseline moderate-severe MR, the greater correction of MR by HPCSP may indicate a better clinical improvement; indeed, at the 6-month follow-up, only 9% of the survivors treated with HPCSP still had advanced heart failure, whereas in the BiVCRT cohort, it was 37%.

4.4 | Conduction system pacing: Combination of HBP and LBBP

In contrast to previous studies, our series included two physiologic pacing methods (HBP and LBBP), that is, HPCSP, as an alternative to conventional BiVCRT, with similar outcomes between pacing the His or the left bundle. The HBP success rate seems to be smaller than that of LBBP, as shown by a high percentage of crossovers (48%) in the *His Sync Trial*.[13] In this context, LBBP is the alternative in those cases where HBP is unable to correct the QRS.

In our study, the success rate increased from 18/27 (66%) to 25/27 (92.5%) when adding LBBP. While the reported LV synchrony was similar between HBP and LBBP, Hu et al further showed that LBBP was a safe strategy in patients with AV block with lower pacing capture thresholds.[20] The lack of differences in beneficial effects between the two conduction system pacing techniques together with the lower pacing threshold may suggest LBBP as an elective technique among CRT candidates, although large studies comparing both techniques are necessary to support this hypothesis.

According to our results, HPCSP could be an alternative approach to provide electrical and mechanical resynchronization in patients with permanent pacing indications and LV dysfunction (LVEF < 45%). These results require confirmation in prospective randomized clinical trials.

4.5 | Limitations

Our study compared a cohort of patients who received HPCSP with a historical cohort of patients treated with BiVCRT. Although patients

in both groups were 1:1 matched, the two cohorts were not contemporaries. During this period, there was an evolution in the medical treatment of heart failure and BiVCRT implants (bipolar vs. multipolar LV electrodes), and all these facts may be detrimental for the CRT cohort. The results should be interpreted with caution, pending parallel randomized studies.

Long-term randomized controlled trials comparing HPCSP with BiVCRT in this subgroup of patients are necessary. If these data are confirmed, we will have HPCSP as an additional tool in the armamentarium of resynchronization therapy.

5 | CONCLUSION

HPCSP with either HBP or LBBP in patients with LVEF ≤45% and a ventricular pacing indication showed an echocardiographic response at 6-month follow-up comparable to that of BiVCRT; moreover, HPCSP significantly improved MR and NYHA functional class. For all these reasons, HPCSP may be an alternative to BiVCRT in patients with LV dysfunction and the need for ventricular pacing due to AV block.

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