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CLINICAL BENEFITS OF SWITCHING FROM RIGHT VENTRICULAR APICAL PACING TO LEFT BUNDLE BRANCH AREA PACING IN PATIENTS WITH COMPLETE ATRIOVENTRICULAR BLOCK: ACUTE RESULTS

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Aim. To evaluate the impact of upgrading from right ventricular apical pacing (RVAP) to left bundle branch area pacing (LBBAP) on the clinical and functional status of patients with complete atrioventricular block (AVB) in the acute period.

Methods. The study included 30 patients with complete AVB and previously implanted pacemakers. All patients underwent elective pacemaker replacement with repositioning of the ventricular lead from the apical site to the LBBAP area. Clinical and instrumental assessments were performed before surgery and on postoperative day 5, including electrocardiography, echocardiography, a 6-minute walk test and quality of life evaluation using the EQ-5D questionnaire.

Results. After conversion to LBBAP, QRS duration decreased (from 158.5±25.5 ms to 111.2±13.8 ms, $p < 0.05$), interventricular and intraventricular dyssynchrony indices (interventricular mechanical delay and time to peak systolic velocity) were reduced, and the degree of mitral regurgitation decreased. The 6-minute walk test distance increased from 368.7±87.06 m to 466.15±127.2 m, and patients reported improved quality of life according to the EQ-5D questionnaire.

Conclusion. Conversion from RVAP to LBBAP leads to improved electrical and mechanical synchrony of cardiac function, which is associated with increased exercise tolerance and enhanced quality of life. LBBAP demonstrates potential as a more physiological and effective alternative to conventional apical pacing.

Key words: cardiac pacing; conduction system pacing; left bundle branch pacing; atrioventricular block; myocardial dyssynchrony

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Implantation of a permanent pacemaker significantly improves survival and quality of life in patients with complete atrioventricular block (AVB) and remains the cornerstone of treatment for bradyarrhythmias [1]. Recent studies have demonstrated that long-term right ventricular apical pacing induces myocardial dyssynchrony due to abnormal mechanical and electrical ventricular activation. This has a detrimental effect on left ventricular (LV) contractile function and subsequently leads to impaired myocardial perfusion, an increased risk of atrial fibrillation, a higher incidence and progression of heart failure (HF), and increased cardiovascular mortality [2]. Consequently, over the past decade, there has been an active search for alternative pacing sites capable of providing more physiological electromechanical ventricular activation. Currently, physiological conduction system pacing (CSP) is recommended in patients with a high percentage of ventricular pacing in order to reduce the risk of adverse outcomes [3].

CSP is a relatively new field of cardiac pacing that continues to gain popularity as a more physiological alternative to conventional right ventricular pacing (RVP) and as a potential substitute for biventricular cardiac resynchronization therapy (CRT) in patients with sinus rhythm and conduction disturbances [4]. One form of CSP is left bundle branch area pacing (LBBAP), which was first described as an alternative to LV resynchronization by Huang et al. in 2017. This pacing modality achieves direct activation of the left bundle branch (LBB) by positioning the pacing lead within the subendocardial region of the interventricular septum [5]. Compared with His bundle pacing (HBP), LBBAP is characterized by easier implantation and lower, more stable pacing thresholds. This pacing strategy has been associated with encouraging clinical outcomes, preservation of myocardial contractile function, improved exercise tolerance, and enhanced quality of life [6].

In 2022 the results of the MELOS registry were published, including 14 European centers and 2,533 patients. The study demonstrated a procedural success rate of 92.4% in patients with bradycardia. Complications related to transventricular lead implantation occurred in 8.3% of cases, while the rate of long-term complications was low and comparable to that observed with conventional right ventricular pacing [7].

Several studies have also shown the efficacy and safety of switching to LBBAP in the treatment of pacing-induced cardiomyopathy caused by prolonged RVP [8]. Transition to LBBAP may also serve as a rescue strategy for patients who do not respond to CRT, resulting in significant improvements in cardiac function and clinical outcomes [9].

The aim of our study was to assess the immediate impact of changing the pacing site from the RVP to LBBAP on the clinical and functional status of patients with complete AVB.

MATHERIALS AND METHODS

The study included 30 patients with previously implanted permanent pacemakers (PM) for complete AVB. The inclusion criteria were age ≥18 years, preserved left ventricular ejection fraction (LVEF ≥50%), and a ventricular pacing burden ≥80%. Patients with atrial fibrillation were not included. All patients were electively admitted to the Department of Surgical Treatment of Complex Cardiac Arrhythmias and Cardiac Pacing at the Republican Cardiology Dispensary (Cheboksary) for planned pacemaker replacement due to battery depletion. The mean pacemaker service life was 7.3 ± 0.8 years. The mean ventricular pacing percentage was 96.5 ± 2.7% (Table 1).

The mean age of the patients (Table 1) was 70.8 ± 8.7 years; 16 patients were male (53.33%) and 14 were female (46.67%). All patients had a high comorbidity burden, which is typical for this age group. Arterial hypertension was present in 29 patients (96.7%). Half of the study population (15 patients) had coronary artery disease; among them, 4 patients (13.3%) had a history of myocardial infarction, and 6 patients (20%) had previously undergone percutaneous coronary intervention. All patients had at least two concomitant diseases. HF was diagnosed in all patients: 17 patients (56.67%) had New York Heart Association (NYHA) functional class III HF, 12 patients (40%) had NYHA class II, and 1 patient (3.33%) had NYHA class I.

All patients were offered surgical intervention consisting of pacemaker reimplantation with relocation of the ventricular pacing lead from the right ventricular apical position to LBBAP. Written informed consent was obtained from all participants. The study complied with ethical standards based on the Declaration of Helsinki of the World Medical Association ("Ethical Principles for Medical Research Involving Human Subjects"), including the 2000 revision, and the "Rules of Good Clinical Practice in the Russian Federation," approved by Order No. 200n of the Ministry of Health of the Russian Federation dated April 1, 2016.

Before and after the surgical intervention (on the fifth postoperative day), all patients underwent 12-lead electrocardiography (ECG), transthoracic echocardiography with

Table 1.

Patient characteristics

Parameter	Значение
Age, years	70.8±8.7
Male, n (%)	16 (53.3)
Female, n (%)	14 (46.7)
Pacemaker mode DDDR	30 (100)
Pacemaker service life, years	7.3±0.8
Ventricular pacing percentage, %	96.5±2.7
CAD, n (%)	15 (50)
PCI, n (%)	6 (20)
Post-MI cardiosclerosis, n (%)	4 (13.3)
Arterial hypertension, n (%)	29 (96.67)
Stroke, n (%)	2 (6.67)
BCA atherosclerosis, n (%)	12 (40)
Diabetes mellitus, n (%)	10 (33.3)
HF pre-stage, n (%)	2 (6.67)
HF stage I, n (%)	27 (90)
HF stage II, n (%)	1 (3.33)
NYHA class I HF, n (%)	1 (3.33)
NYHA class II HF, n (%)	12 (40)
NYHA class III HF, n (%)	17 (56.67)

Note: PM - permanent pacemaker; PCI - percutaneous coronary intervention; CVA - cerebrovascular accident; BCA - brachiocephalic arteries; HF - heart failure; FC - functional class.

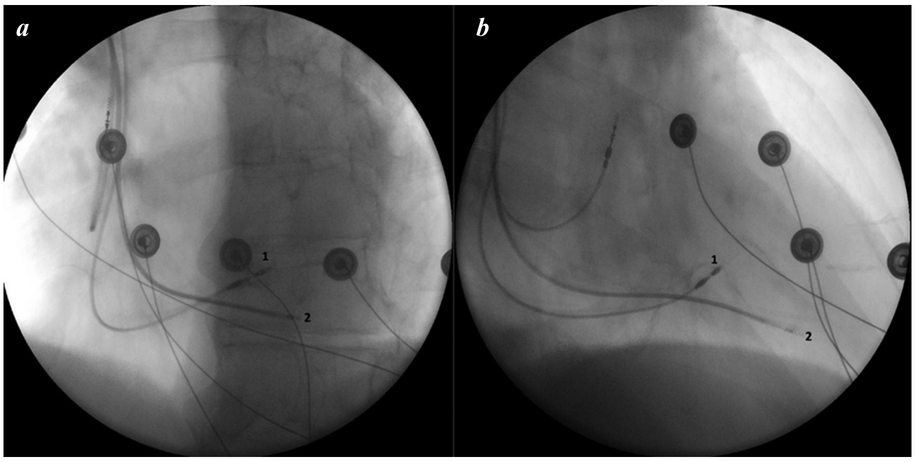

Figure 1. Intraoperative fluoroscopy in the left (a) and right (b) oblique projections, where 1 indicates the ventricular lead positioned in the left bundle branch area and 2 indicates the previous ventricular lead in the apical position.

additional assessment of myocardial dyssynchrony parameters, a six-minute walk test, and quality-of-life evaluation using the EQ-5D questionnaire.

During the procedure a modified stylet with two curves was used to position the pacing lead in the mid-septal region of the interventricular septum: a larger curve directed toward the right ventricle and a smaller curve to achieve maximum of perpendicular orientation of the lead relative to the interventricular septum. Lead position was confirmed using fluoroscopy in right and left anterior oblique projections at 30 degrees (Fig. 1). After meeting the criteria for left bundle branch capture during unipolar pacing, the effectiveness of pacing in bipolar mode was also assessed. If left bundle branch capture was not achieved in bipolar mode, additional rotations of the lead were performed to advance it deeper into the septum (Fig. 2). Once the final lead position was achieved, the stylet was removed and the lead was secured to the soft tissues.

Statistical analysis

Statistical analysis of the obtained data was performed using Statistica 10.0 software. Quantitative variables were assessed for normality using the Shapiro-Wilk test. Quantitative data were expressed as mean (M) ± standard deviation (SD) in the case of a normal distribution, and as median (Me) with lower and upper quartiles (Q1-Q3) when the distribution was non-normal.

Figure 2. Changes in QRS morphology during stepwise advancement of the pacing lead within the interventricular septum on standard 12-lead ECG recordings: (a) native QRS complex without pacing; (b) left ventricular septal pacing (V6 RWPT = 78 ms, interpeak interval in leads V6-V1 = 47 ms); (c) non-selective left bundle branch pacing (V6 RWPT = 76 ms, interpeak interval in leads V6-V1 = 40 ms); (d) selective left bundle branch pacing (V6 RWPT = 60 ms, interpeak interval in leads V6-V1 = 54 ms).

Comparisons between variables were performed using parametric statistical methods, specifically the Student's t-test for comparison of two independent samples. Differences were considered statistically significant at $p < 0.05$.

RESULTS

After changing the ventricular pacing site from the apical position to LBBAP, we observed a number of changes in both electrocardiographic and echocardiographic parameters (Table 2). The mean QRS duration decreased significantly from 158.5 ± 25.5 ms before the procedure to 111.2 ± 13.8 ms after implantation ($p < 0.05$).

In all patients, myocardial dyssynchrony was reduced after the procedure, as reflected by a decrease in interventricular mechanical delay (IVMD) from 33.3 ± 24.2 ms to 15.8 ± 13.4 ms, and a reduction in septal-to-lateral delay measured as time to peak systolic velocity (Ts TDI) from 49.3 ± 34.2 ms to 21.4 ± 17.4 ms, indicating improved intraventricular synchrony. In addition, the severity of functional mitral regurgitation decreased from 17.05 ± 10.01% to 11.53 ± 9.24% ($p < 0.05$).

No statistically significant differences were observed in LVEF, cardiac chamber dimensions, or global longitudinal strain (GLS) before and after the procedure, most likely due to the early timing of follow-up echocardiography performed on postoperative day 5. It is evident that a longer follow-up period is required to assess dynamic changes in these parameters.

All patients underwent a six-minute walk test after the procedure. With LBBAP, the walking distance increased to 466.15 ± 127.2 m, compared with 368.7 ± 87.1 m during apical pacing ($p < 0.05$), representing an improvement of more than 25%. According to the EQ-5D quality-of-life questionnaire, the health status score increased from 61.2 ± 13.2% at baseline to 71.8 ± 14.9% after the procedure ($p < 0.05$).

DISCUSSION

We identified clear advantages of transitioning from RVP to LBBAP, reflecting its greater physiology and potential effectiveness in providing optimal electrical and mechanical myocardial synchrony. Similar findings have been reported in several contemporary studies. For example, G. Dell'Era et al. demonstrated early echocardiographic changes in 50 patients following initiation of LBBAP, showing improvement in both interventricular and intraventricular dyssynchrony. This was achieved through a reduction in the time-to-peak strain standard deviation derived from the interventricular septum and the left ventricular lateral wall from 38.2 (13.6-53.9) ms to 15.1 (8.3-31.5) ms ($p < 0.001$), as well as between the interventricular septum and the right ventricular free wall from 27.9 (10.2-41.5) ms to 13.9 (4.3-28.7) ms ($p = 0.001$) [11].

Our findings are consistent with the results reported by W. Y. Yang et al., who also demonstrated favorable electrocardiographic and echocardiographic effects following transition to LBBAP [12]. Their study included 40 patients and evaluated QRS duration, LVEF, septal-to-posterior wall motion delay, IVMD, and the maximal difference in time to peak systolic strain among 18 left ventricular segments (TDmax). According to their results, IVMD was significantly shorter in the LBBAP group (-5.38 ± 9.31 ms) compared with both RVP (44.8 ± 16.4 ms) and septal pacing (25.3 ± 21.4 ms). Septal-to-posterior wall motion delay was also markedly lower in the LBBAP group (28.7 ± 21.9 ms) than in the apical and septal pacing groups, where values were approximately threefold higher (99.1 ± 46.6 ms and 91.5 ± 26.7 ms, respectively). TDmax was longest in the RVP group (189.8 ± 91.9 ms) and significantly shorter with LBBAP (87.6 ± 56.0 ms), confirming the association of LBBAP with reduced myocardial dyssynchrony.

It should be noted that our study was limited to the early postoperative period (day of re-implantation and postoperative day 5), which precluded assessment of long-term clinical outcomes. However, data from a large registry by P. S. Sharma et al., including 703 patients (LBBAP: 321; RVP: 382) with a mean follow-up of 583 ± 274 days, demonstrated a clear long-term advantage of LBBAP over apical pacing. All-cause mortality was significantly higher in the RVP group (23.3% vs 10% with LBBAP). Moreover, analysis stratified by ventricular pacing burden revealed a significant mortality difference among patients with >40% ventricular pacing: 8.6% (19/220) in the LBBAP group versus 27.6% (53/192) in the RVP group ($p < 0.001$). During follow-up, a total of 52 heart failure decompensation events requiring hospitalization were recorded, with 3.7% (12/332) occurring in the LBBAP group and 10.5% (40/382) in the RVP group [13].

According to several smaller observational studies, a longer follow-up period is required to adequately assess myocardial remodeling and changes in functional capacity. In the study by Y. Shan et al., a 12-month follow-up of patients with pacing-induced cardiomyopathy due to RVP showed that upgrading to LBBAP resulted in a significant increase in LVEF from 36.6 ± 7.2% to 51.3 ± 8.7% ($p < 0.001$) and a reduction in left ventricular end-diastolic diameter from 61.5 ± 6.4 mm to 55.2 ± 6.5 mm ($p < 0.001$) [14]. A meta-analysis of eight observational studies involving 217 patients (mean baseline LVEF 38.4 ± 8.8%) demonstrated that transition to conduction system pacing not only improved LVEF but also reduced NYHA functional class and, consequently, improved patients' quality of life [15].

Ongoing large international trials evaluating the efficacy and safety of conduction system pacing (PROTECT-HF, OptimPacing, Protect-Sync, LEAP-Block, PHYSPAVB) may substantially influence future guideline recommendations for the management of patients with conduction disorders and promote wider adoption of conduction system pacing in clinical practice across diverse patient populations.

CONCLUSION

1. Conversion from RVP to LBBAP in patients with preserved baseline left ventricular systolic function results in a more physiological pattern of ventricular activation, as evidenced by a reduction in QRS duration. This transition is associated with decreased electrical and mechanical myocardial dyssynchrony, leading to improved intracardiac hemodynamics. As a result, patients demonstrate increased exercise tolerance and, consequently, improved quality of life.
2. In the long-term perspective, LBBAP may promote reverse myocardial remodeling with improvement in left ventricular contractile function, which is expected to translate into a reduction in heart failure symptoms, fewer heart failure-related hospitalizations, and a decreased burden on the healthcare system.

Table 2.

Electrocardiographic and echocardiographic data, quality-of-life indicators, and six-minute walk test results in patients before and after surgery

Parameter	Before surgery	After surgery	p
QRSduration, ms	158.5±25.5	111.2±13.8	<0.05
IVMD, ms	33.3±24.2	15.8±13.4	<0.05
Ts TDI, ms	49.3±34.2	21.4±17.4	<0.05
AV-dyssynchrony	51±3.6	53.1±2.8	0.179
GLS	-14.4±2.7	-15.2±2.4	0.483
LVEF, %	59.7±5.1	61.4±4.2	0.12
LVEDD, cm	5.04±0.44	5.02±0.42	0.448
LVESD, cm	3.38±0.31	3.37±0.29	0.402
LVEDV, mL	121.01±26.62	119.0±25.3	0.143
LVESV, mL	47.09±18.74	46.17±18.55	0.140
MR, %	17.05±10.01	11.53±9.24	<0.05
mPAP, mmHg	30.8±9.5	29.3±10	0.622
6MWT, m	368.7±87.06	466.15±127.2	<0.05
EQ-5D*, %	61.2±13.2	71.8±14.9	<0.05

Note: LVEF - left ventricular ejection fraction; LV - left ventricle; LVEDD - left ventricular end-diastolic diameter; LVESD - left ventricular end-systolic diameter; LVEDV and LVESV - left ventricular end-diastolic and end-systolic volumes; MR - mitral regurgitation; mPAP - mean pulmonary artery pressure; IVMD - interventricular mechanical delay; Ts TDI - time to peak systolic velocity (septal-to-lateral delay); GLS - global longitudinal strain; 6MWT - six-minute walk test; * - health status scale.

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