Postol A. S.[1], Neminushchiy N. M.[2], Antipov G. N.[1], Ivanchenko A. V.[1], Lyashenko V. V.[1], Kalinin D. A.[1], Kotov S. N.[1], Vygovsky A. B.[1], Schneider Yu. A.[1]

[1] Federal Center of High Medical Technologies, Kaliningrad, Russia

[2] Sechenov First Moscow State Medical University, Moscow, Russia

Factors that Determined a Positive Response to Resynchronization Therapy in Patients With Chronic Heart Failure and Cardiac Dyssynchrony. One Center Experience

Aim — To evaluate the efficacy of cardiac resynchronization therapy (CRT) in patients with chronic heart failure (CHF) associated with cardiac dyssynchrony and to identify the factors that influence the CRT efficacy.

Material and methods — This retrospective study included 155 patients after implantation of CRT devices. The CRT devices with a built-in cardioverter-defibrillator (CRT-D) and without it (CRT-P) were implanted in 139 (89.7%) and 16 (10.3%) patients, respectively. The follow-up period was 52.37±35.94 months. Based on the study results, two groups of patients were formed depending on the presence of a clinical response to CRT, responders and non-responders. The factors that influenced the clinical response to CRT were studied. The effect of the baseline state of patients on the effect of therapy was assessed. The need for CRT optimization and a possibility of using electrocardiographic criteria for that purpose were studied. Modern devices and leads for CRT, their functional capabilities and their influence on the CRT efficacy were characterized. Statistical analysis was performed with an IBM SPSS Statistics 21.0 (Chicago, USA) package.

Results — CRT implantation with the left ventricular lead placement according to the traditional technique, through the coronary sinus, was successful in 130 (87.9%) patients. Difficulties with the left ventricular lead placement were noted in 13 (8.3%) patients when other techniques were used. After 6 months, a hemodynamic and clinical response was observed in 112 (72.2%) patients, and no positive response in 43 (27.8%). The increase in left ventricular ejection fraction in the responder group was more than 21.8±3.7%, which was associated with an improvement of the 6-minute walk test results. Th clinical response was significantly influenced by the possibility of stimulation from the basal parts of the heart; the use of more modern devices for CRT and quadripolar left ventricular leads; timely CRT optimization; and persistent dyssynchrony in non-responders. During the follow-up period, 34 (21.9%) patients died. The death rate in the non-responder group was significantly higher than in the responder group, 18 (41.3%) vs. 16 (14.3%), p=0.001. The main cause of death in the group of non-responders was CHF. Heart transplantation was performed in 3 (1.9%) patients.

Conclusion — CRT increases the life span and improves the quality of life in patients with CHF and cardiac dyssynchrony. There was a group of patients with no benefit from CRT in this study. Modern devices allow increasing the number of patients who benefit from CRT. Periodic optimization of CRT is necessary. When optimizing CRT, it is possible to use electrocardiographic criteria of effectiveness: duration of the QRS complex and changes in the position of the electrical axis of the heart.

Keywords — Resynchronization therapy; chronic heart failure; cardiac dyssynchrony; left bundle branch block; QRS complex duration; quadripolar lead

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Corresponding author — Postol A. S. E-mail: postol-75@mail.ru

Introduction

Cardiac resynchronization therapy (CRT) represents an efficacious and substantiated approach to treating patients with chronic heart failure (CHF) and dyssynchronous ventricular contractions resulting from eccentric propagation of excitation through the ventricular myocardium due to bundle branch

block, impaired intraventricular conduction, and continuous right ventricular stimulation. In accordance with contemporary clinical guidelines and research evidence [1–5], the primary indication for CRT is clinically manifest CHF in the presence of left bundle branch block (LBBB) with a QRS complex duration of 130 milliseconds or more (class I, level of evidence A). The results of numerous well-designed clinical studies indicate that CRT is an effective intervention for improving survival, reducing the progression of CHF, and decreasing the number of hospitalizations. Additionally, it has been demonstrated to enhance functional status and quality of life in these patients. The mechanisms of the therapeutic effect of CRT are dependent upon the precise setting of the time interval between atrial and ventricular activation (AV delay) and the time interval between right and left ventricular activation (VV delay). The former mechanism is responsible for the effective diastolic filling of the ventricles, whereas the latter mechanism is accountable for the simultaneous synchronous contraction of all segments of the left ventricle (LV), predominantly the interventricular septum (IVS) and its posterolateral wall. The administration of CRT necessitates periodic optimization, namely, the adjustment of stimulation parameters, primarily AV and VV delays, under echocardiographic control or other hemodynamic monitoring methods, with the objective of achieving optimal hemodynamic parameters at an average frequency of once every 3–6 months [6–8]. The frequency of CRT optimization is largely contingent upon the changes in the patient's condition and the specific type of implanted device. For example, many contemporary devices are equipped with automated AV and VV delay adjustment capabilities. This enables the optimization of patient visits to clinics, facilitating the use of the device and enabling the continuous dynamic optimization of CRT in response to the patient's changing needs and circumstances [8–10]. In the initial stages of the method's development, it was demonstrated that a minimum of 30% of patients exhibited no response to CRT, thereby classifying them as non-responders [11–13]. Despite the placement of an implantable CRT device, the desired hemodynamic and clinical effects could not be achieved in these patients. A review of recent literature reveals a decline in the number of these patients, with the proportion ranging from 10% to 20%. Nevertheless, there are cases in which patients, along with super-responders, have demonstrated a substantial enhancement in their functional and clinical status, nearly reaching complete cardiac function recovery. Such patients are those who have achieved a reduction in end-systolic volume (ESV) of at least 30% and an increase in left ventricular ejection fraction (LVEF) of at least 10–12% as a result of CRT [14, 15]. The variability in the effects of CRT has consistently stimulated considerable interest among researchers, prompting a multitude of investigations into the factors contributing to CRT efficacy and the prognostic value of these factors. The following factors are currently known to be commonly relevant: the optimal and suboptimal settings of AV and VV delays; insufficient proportion of biventricular stimulation in the heart rhythm, less than 90%; incorrect position of the left ventricular electrode; complications, including diaphragmatic stimulation, electrode dislocation, and increased stimulation threshold; indirect factors, such as inadequate drug therapy and comorbidities; and persistent electromechanical dyssynchrony of myocardial contractions [7, 8].

The aforementioned issues were addressed by manufacturers through the enhancement of RT devices and the introduction of novel functionalities. As previously stated, devices equipped with automatic CRT optimization algorithms have become available. Four-pole electrodes, which possess the capacity to alter the polarity of stimulation and consequently modify its vector through the utilization of a programmer for the CRT device, were introduced into clinical practice. The concept of electrical electrode repositioning was developed, whereby the point of application of stimulation is altered by modifying the polarity of the electrode. It was thus possible to avoid diaphragmatic stimulation and to select the polarity with the lowest stimulation thresholds and optimal myocardial capture zone without the necessity for surgical intervention.

The Kaliningrad Federal Center for High Medical Technologies has been engaged in the implantation of CRT systems since 2012. Subsequent follow-up of patients has been conducted, including procedures to optimize and adjust the implanted devices. Over the past several years, a substantial amount of experience has been accumulated in the management of these patients. This paper presents a summary of the results obtained over a specific period of time. It also attempts to identify predictors of a positive response to CRT and to evaluate factors affecting the efficacy of resynchronization therapy.

Material and Methods

The retrospective study included 155 patients who received implantable CRT devices between November 2012 and May 2023 at the Kaliningrad Federal Center for High Medical Technologies.

The study included patients who met the following criteria: clinically significant CHF class II–IV according to the New York Heart Association (NYHA) classification system, LVEF ≤ 35%, QRS complex duration exceeding 150 ms, and LBBB morphology. All patients were treated with the best possible medical therapy. The exclusion criteria were as follows: QRS complex was less than 150 ms or non-LBBB morphology; a history of cerebrovascular accident, autoimmune or active inflammatory myocardial diseases, thyrotoxicosis diagnosed prior to the inclusion, diseases with a life expectancy of less than one year, or a history of myocardial infarction of less than 40 days.

Among the patients, 139 (89.7%) had CRT devices with cardioverter-defibrillator functionality (CRT-D), while 16

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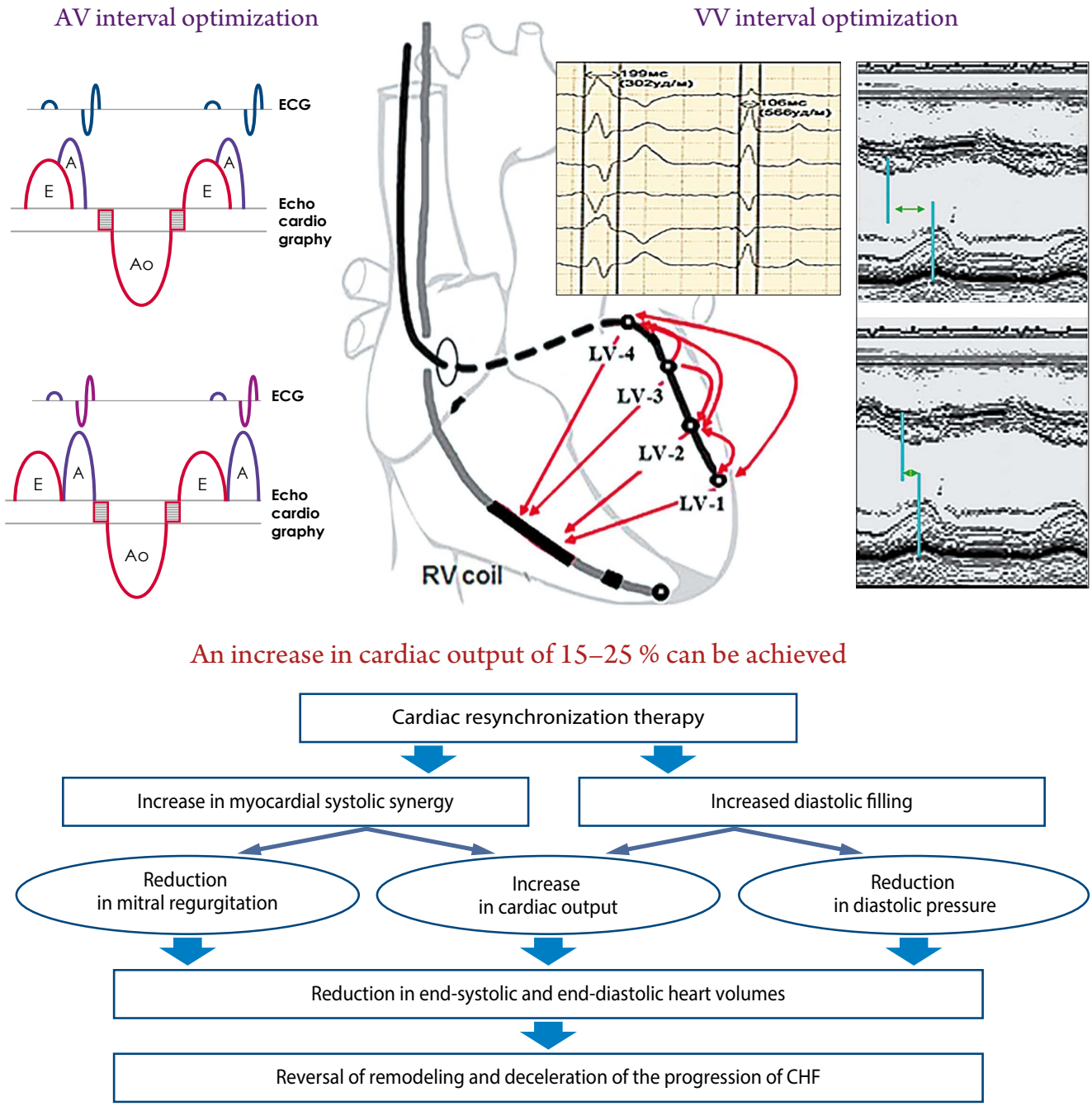
Central illustration. Factors that Determined a Positive Response to Resynchronization Therapy in Patients With Chronic Heart Failure and Cardiac Dyssynchrony. One Center Experience



(10.3%) had devices without such functionality (CRT-P, P is for pacemaker). The CRT devices were implanted in accordance with the indications delineated in the clinical guidelines of the Ministry of Health of the Russian Federation and the European Society of Cardiology [1–3].

The Ethics Committee of the Kaliningrad Federal Center for High Medical Technologies approved a retrospective uncontrolled study with an interrupted time series comprising two groups of patients, distinguished by their response to CRT (minutes #7 dated September 2, 2023).

The primary indication for the implantation of CRT devices in all patients was clinically significant CHF of NYHA class II–IV, LVEF ≤ 35%, and an extended QRS complex of more than 150 ms with LBBB morphology (150 patients, 96.8%). Moreover, CRT was performed on 5 (3.2%) pediatric patients. The median age was 41 (14–58) months. In 79 cases (51%), the underlying cause of CHF was coronary heart disease, while in 76 cases (49%), the cause was non-ischemic cardiomyopathies. The clinical characteristics of the patients are presented in Table 1.

Prior to device implantation, all patients (n = 155; 100%) underwent a comprehensive standard clinical examination, 12-lead electrocardiography, echocardiography, coronary angiography (except for pediatric patients), and magnetic resonance imaging of the heart. All patients were provided with the best possible medical treatment in accordance with the severity of CHF. Table 2 provides an overview of the implantable CRT devices with their respective origins. During the follow-up period, 59 (38%) patients underwent re-implantation – the device was replaced due to depletion of the power supply. Of these patients, 12 (7.7%) underwent two replacements of the device.

The CRT implantation was performed using the conventional technique, with the left ventricular electrode placement through the coronary sinus and cardiac venous system in 130 (87.9%) patients. In 9 (5.8%) patients, the left ventricular electrode was placed transseptally directly into the LV cavity. In 16 (10.3%) patients, the left ventricular electrode was implanted epicardially. In 135 (87.1%) cases, the right ventricular electrode was implanted in the apex region, while in 20 (12.9%) cases, it was placed in the IVS region. Implantation of the right atrial electrode was the final step. Figure 1 illustrates the positioning of electrodes within the cardiac structure. The goal was to situate the left ventricular electrode in the LV posterolateral wall region and stimulate the basal regions, which proved to be a significant challenge when using bipolar electrodes. Figure 1 illustrates a quadripolar left ventricular electrode, which enables stimulation from the LV-2-LV-3 poles in close proximity to the basal regions. In order to prevent the triggering of myocardial depolarization from the anode (anodal stimulation), the shock coil of the right ventricular electrode in CRT-D or the corpuscle in CRT-P was utilized as the anode.

During the implantation procedure, the standard electrical parameters were determined, including the signal amplitude, stimulation threshold, presence of stimulation of the diaphragmatic nerve, and impedance during stimulation. In the event of non-compliance with the established parameters, the electrode position was duly adjusted. The primary programming of the device and the settings of the AV and VV delays were completed at the conclusion of the procedure in order to obtain the narrowest QRS complex in the standard and thoracic ECG leads. The defibrillator function was initiated in the CRT-D device. On the subsequent day following implantation, programming was conducted based on repeated assessment of morphology and duration of the stimulated QRS complex and echocardiographic picture. This was done using the methodology whereby AV delay was determined by the best values of LV diastolic filling, while VV delay was determined by the minimum delay between the systolic peaks of the IVS and the LV posterior wall. In the case of more contemporary devices, the automatic optimization algorithms for CRT were initiated. Subsequently, patients were examined prior to discharge, at three months post-discharge, and then at six-month intervals thereafter. undertake device programming and CRT optimization was predicated on the patient's clinical status. In the event of a deterioration in the patient's condition, the procedure was conducted at an unscheduled time. The mean follow-up period was 52.37 ± 35.94 months. The follow-up process was carried out through patient visits to the clinic. The remote monitoring system was

Table 1. Clinical characteristics of the patients (n = 155)

Parameter	Value
Age, years (M ± SD)	60.46 ± 15.46
Male / female, n (%)	99 / 56 (63.9 / 36.1)
AF, n (%)	58 (62.6)
CAD, n (%)	79 (51.0)
DCM, n (%)	76 (49.0)
LVEF, % (M ± SD)	24.29 ± 5.62
Valve correction, n (%)	36 (23.2)
Revascularization, n (%)	79 (51.0)
LVESV, mm (M ± SD)	181.14 ± 58.69
LVEDV, mm (M ± SD)	250.77 ± 71.89
MVI grade 1, n (%)	2 (1.3)
MVI grade 2, n (%)	121 (78.0)
MVI grade 3, n (%)	32 (20.69)
QRS duration, msec (M ± SD)	178.86 ± 18.31
CHF class II, n (%)	2 (1.3)
CHF class III, n (%)	131 (84.5)
CHF class IV, n (%)	22 (14.2)
Hypertension, n (%)	120 (77.4)
Diabetes mellitus, n (%)	42 (27.1)

DCMP, dilated cardiomyopathy; MVI, mitral valve insufficiency.

Table 2. Models of CRT devices implanted in patients

Number of patients, n (%)	CRT-D/ CRT-P	Device	Manu-facturer	Country of origin
5 (3.2)	RT-D	Intica Neo	Biotronik	Germany
2 (1.3)	RT-P	Evia	Biotronik	Germany
1 (0.6)	RT-P	Valitude	Boston Scientific	USA
103 (66.4)	RT-D	Protecta	Medtronic	USA
11 (7.1)	RT-D	Brava	Medtronic	USA
3 (1.9)	RT-D	Claria	Medtronic	USA
2 (1.3)	RT-D	Maximo II	Medtronic	USA
2 (1.3)	RT-D	Protecta XT	Medtronic	USA
8 (5.1)	RT-D	Viva	Medtronic	USA
13 (8.4)	RT-P	Consalta	Medtronic	USA
4 (2.6)	RT-D	Unify Quadra	Abbott	USA
1 (0.6)	RT-D	Quadra Assura	Abbott	USA

CRT, cardiac resynchronization therapy; CRT-D, cardiac resynchronization device with defibrillation function; CRT-P, cardiac resynchronization device without defibrillation function, P, pacemaker.

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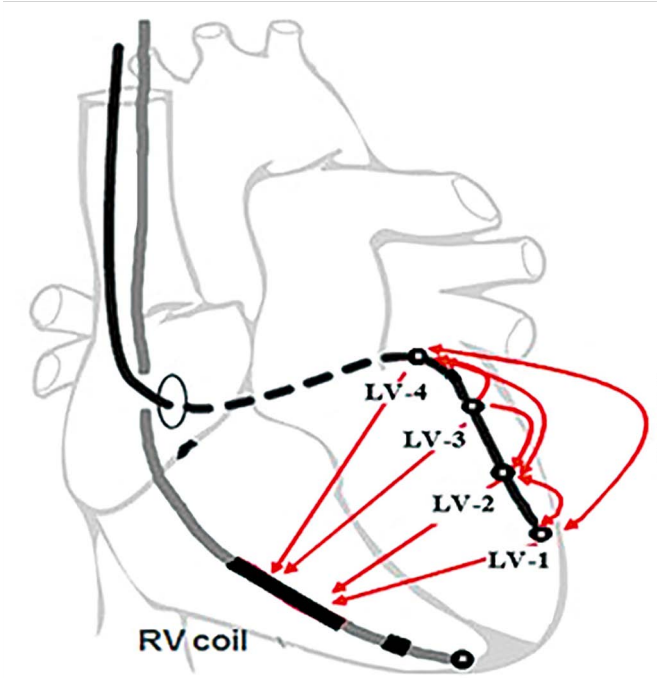
Figure 1. Arrangement of the right and left ventricular electrodes with the potential alterations to the polarity of the left ventricular electrode stimulation (LV-1, LV-2, LV-3, LV-4)

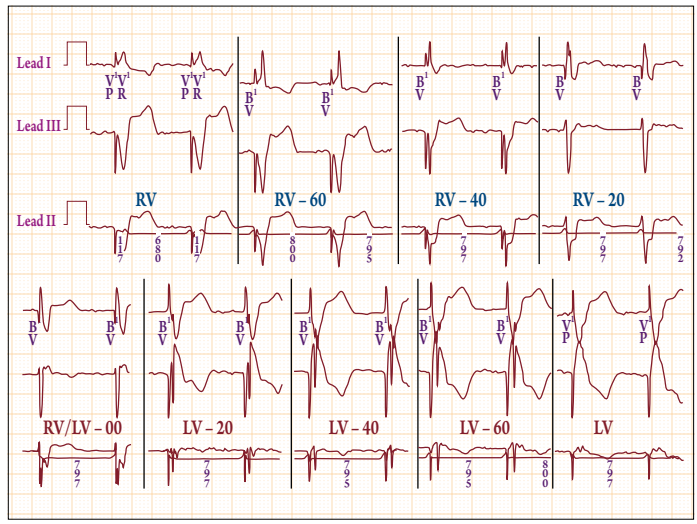


The red arrows indicate potential combinations of positive and negative poles of the stimulation electrodes; a shock coil on the surface of the RV coil can serve as a positive pole. A programming device allows for the connection of either one pole of the four poles of the left ventricular electrode or any two poles together, thereby facilitating the capture of LV myocardium. In the majority of cases, stimulation was applied from the LV-3 and LV-2 poles.

employed in 139 (89.7%) patients to obtain information via the Internet. Primarily, the patient's condition was evaluated based on the progression of CHF. The diagnostic information obtained from the CRT devices was evaluated, including the patient's heart rate at daytime and at night, its variability, the presence of arrhythmia episodes, the patient's activity index, the index of fluid accumulation in pulmonary tissue, and the proportion of biventricular stimulation. In the event that the latter was less than 90% of the patient's rhythm, the underlying causes for this decline were elucidated, and measures were undertaken to enhance its level. Therefore, the presence of tachysystolic atrial fibrillation (AF) necessitated the incorporation of algorithms that augmented the percentage of stimulated ventricular complexes; the prescription of pharmaceutical agents that diminished the frequency of ventricular rhythm; and radiofrequency ablation (RFA) in the region of pulmonary veins, and in some cases the complete transverse heart block using RFA. The optimization of CRT under ECG control was aimed at achieving the narrowest QRS complex in standard and thoracic leads and at obtaining signs of dominant LV myocardium stimulus capture, which was confirmed by the rightward deviation of the electrical axis of the heart. Figure 2 depicts the alteration in the morphology of the QRS complexes and the deviation of the electrical axis of the heart at varying delays (VV) between the stimuli applied to the RV and LV. The right axis deviation is observed when the LV stimulus is applied in advance of the RV stimulus. In such instances, there is a preferential capture of the LV. In the absence of positive changes, we proceeded with optimizing CRT under echocardiographic control. In 79 (71%) patients, the stimulation vector was modified by altering its polarity in the appropriate CRT systems, thereby facilitating early activation of myocardial zones that had been activated the latest at spontaneous rhythm; early, dominant capture of the LV in relation to the RV [16]; and avoidance of diaphragmatic stimulation. The positive response to CRT (responder group) was defined as an increase in LVEF by 10% or more and a reduction of CHF NYHA class 6 months after the implantation. The non-responders were defined as those who were not included in the group of responders, deceased patients, and patients who were hospitalized for CHF during the specified period.

The statistical analysis of the collected data was performed using the IBM SPSS Statistics 21.0 software (USA). Categorical variables were expressed as percentages, while continuous variables were presented as mean ± standard deviation (M ± SD). Comparisons between the two groups

Figure 2. Changes in the duration and morphology of QRS complexes when varying the delay between ventricular stimuli (VV delay)



The initial two complexes entail the stimulation of the right ventricle (RV), while the subsequent two complexes exhibit a 60 ms advancement in the of onset of the RV stimulation relative to the left ventricular (LV) stimulation. Subsequently, the RV is observed to outpace the LV by 40 ms, then by 20 ms, followed by 0 ms. Thereafter, the LV is seen to outpace the RV by 20, 40, and 60 ms, with the final two complexes representing the stimulation of the LV alone. The electrical axis of the heart undergoes a gradual shift from a horizontal to a vertical position. Stimulation with dominant LV capture is distinguished by a more vertical position of the axis.

were conducted using Student's t-test for continuous variables and Pearson's chi-squared test for categorical variables. Kaplan-Meier survival models were utilized to estimate survival at each time point.

The differences were considered to be statistically significant at the $p < 0.05$ level.

Results

The implantation of CRT with the left ventricular electrode installment through the coronary sinus using the traditional technique was successful in 130 (87.9%) patients. In 13 patients (8.3%), the placement of the left ventricular electrode through the cardiac venous system was found to be challenging. In these patients, the left ventricular electrode was placed either transseptally (n = 9, 5.8%) or epicardially (n = 4, 2.5%). In pediatric patients, the electrodes were also placed epicardially (n = 5, 3.2%). Table 3 shows the correlation between the baseline clinical characteristics of patients and the subsequent clinical response to CRT. Significant intergroup differences were observed in ESV and end-diastolic volume (EDV) of the LV, which were markedly higher in patients who did not respond to CRT compared to those who exhibited a positive response. Moreover, the mean LVEF was observed to be lower and the mean QRS duration was longer in the non-responder group than in the responder group. Nevertheless, these discrepancies did not reach statistical significance. In general, it can be stated that patients presenting with an initially more severe condition subsequently demonstrated a lack of expected response to CRT.

A hemodynamic and clinical response was observed in 112 (72.2%) patients within a six-month period. Conversely, 43 (27.8%) patients exhibited an absence of positive response to CRT despite optimization. The group of patients who responded to CRT exhibited pronounced a marked improvement in LVEF, with an increase of over 21.8 ± 3.7%. Furthermore, they demonstrated a notable enhancement in exercise tolerance, as evidenced by the results of the 6-minute walk test (Table 4). Statistically significant differences between the groups were observed immediately following surgery and were associated with the positioning of the left ventricular electrode, which was largely influenced by the anatomy of the LV coronary veins. As demonstrated in Table 4, the possibility of LV stimulation from the basal regions of the posterolateral and lateral LV wall is prevalent in 108 (96.7%) patients within the responder group. Conversely, LV stimulation from the apical region of the lateral and posterior LV walls is more prevalent among non-responders, occurring in 22 (51.1%) patients. The duration of the QRS complex in the presence of stimulation was found to be significantly longer in the non-responder group, indicating the presence of dyssynchrony despite the use of CRT. Moreover, the persistence of dyssynchrony in the non-responder group is substantiated by echocardiographic data. The values of interventricular dyssynchrony, as indicated by Doppler echocardiography (defined as the discrepancy between the intervals from the Q wave preceding the onset of ejection into the aorta and the onset of ejection into the pulmonary artery), and the values of intraventricular dyssynchrony (defined as the delay between the systolic peaks of the INS and the LV posterior wall in the M mode) were found to be significantly different between the two groups. In addition to the aforementioned factors, the positive response to CRT among patients was influenced by the possibility of therapy optimization. Thus, with regard to manual optimization, one of the factors that influenced the efficacy of CRT was the right axis deviation during stimulation, which confirms the effective capture of LV. The use of more contemporary devices, which possess the capacity to alter the stimulation vector and the algorithms of automatic optimization of CRT, also exerted a considerable influence on the favorable response observed among patients with CRT devices (Table 4).

The prevalence of AF was approximately equal in both groups of patients. The efficacy of CRT was diminished due to AF, yet the presence or absence of a therapeutic response remained unaltered. The only significant discrepancy was observed in the

Table 3. Baseline (prior to the implantation of a resynchronization device) clinical characteristics of patients who responded to CRT and those who did not

Parameter	All patients (n = 155)	Responders (n = 112; 72.2 %)	Non-responders (n = 43; 27.8 %)	p
Age, years (M ± SD)	60.46 ± 15.46	60.31 ± 17.3	60.86 ± 9.36	0.203
Male / female, n (%)	99/56 (63.9/36.1)	68/44 (60.7/39.3)	31/12 (72/28)	0.128
LVEF, % (M ± SD)	24.29 ± 5.62	24.63 ± 5.65	23.27 ± 5.48	0.984
LVESV, mm (M ± SD)	181.14 ± 58.69	171.88 ± 57.08	205.3 ± 56.53	0.000
LVEDV, mm (M ± SD)	250.77 ± 71.8	240.30 ± 73.2	278.05 ± 61.04	0.001
Paroxysmal AF, n (%)	11 (7.10)	8 (7.14)	3 (6.98)	0.576
Persistent AF, n (%)	21 (13.55)	17 (15.18)	4 (9.30)	
CHD after revascularization, n (%)	79 (50.96)	44 (28.38)	35 (22.58)	0.111
Duration of spontaneous QRS (complex), msec (M ± SD)	178.86 ± 18.31	177.70 ± 16.96	181.88 ± 21.35	0.189

CRT, cardiac resynchronization therapy.

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Table 4. Clinical outcomes of CRT among patients who responded to the treatment and those who did not, 6 months after implantation

Parameter	All patients (n = 155)	Responders (n = 112; 72.2 %)	Non-responders (n = 43; 27.8 %)	p
LVEF, % (M ± SD)	39.83 ± 11.87	45.39 ± 8.02	25.33 ± 6.97	0.000
Increase in LVEF, %	16.25 ± 12.01	21.76 ± 8.85	1.88 ± 5.49	0.000
6 minute walk test, m	357.89 ± 102.5	394.73 ± 71.82	262.79 ± 109.27	0.000
LV stimulation at basal sites, n (%)	131 (84.5)	108 (96.4)	21 (48.8)	0.000
QRS duration during stimulation, msec (M ± SD)	139.66 ± 20.55	133.27 ± 17.61	156.33 ± 18.31	0.000
Right axis deviation during stimulation, n (%)	110 (71.0)	95 (84.8)	15 (34.9)	0.001
Change in stimulation vector, n (%)	75 (48.38)	62 (40.0)	13 (8.38)	0.053
Automatic optimization of CRT, n (%)	65 (41.9)	55 (49.1)	10 (23.3)	0.003
Interventricular mechanical dyssynchrony on echocardiogram (M ± SD)	22.84 ± 8.75	21.90 ± 6.3	26.75 ± 14.89	0.148
Interventricular dyssynchrony on echocardiogram (M ± SD)	79.21 ± 62.19	66.36 ± 51.41	131.25 ± 75.32	0.000
Pulmonary vein ablation in AF (RFA), n (%)	16 (10.3)	5 (4.5)	11 (25.6)	0.000
Creation of a heart block (AV node RFA), n (%)	16 (10.3)	10 (8.9)	6 (14.0)	0.259
Areas of local fibrosis on MRI, n (%)	38 (24.5)	20 (17.8)	18 (41.9)	0.002
Death of CHF, n (%)	12 (7.7)	0	12 (27.9)	0.000
Death of Covid-19, n (%)	10 (6.5)	6 (5.4)	4 (9.3)	0.372
Death, all other causes, n (%)	12 (7.7)	12 (10.7)	—	0.026
All-cause mortality, %	34 (21.9)	16 (14.3)	18 (41.3)	0.001
Heart transplantation, n (%)	3 (1.9)	1 (0.9)	2 (4.65)	0.130

CRT, cardiac resynchronization therapy; RFA, radiofrequency ablation; AV, atrioventricular.

number of patients who underwent pulmonary vein RFA due to severe episodes of AF in the non-responder group (Table 4).

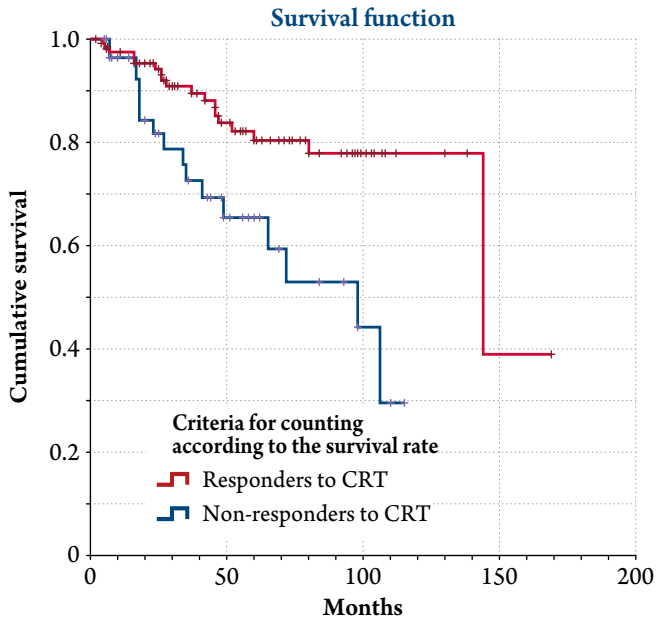
During the follow-up period, 34 (21.9%) patients died. As anticipated, the mortality rate was significantly elevated among the non-responders (n = 18, 41.3%) compared to the responders (n = 16, 14.3%; p = 0.001; Figure 3). The primary cause of mortality among non-responders was CHF. In light of the considerable impact of the ongoing Covid-19 pandemic on mortality rates during the follow-up period, we have presented mortality data from this cause separately. A total of 3 (1.9%) patients underwent heart transplantation.

Discussion

Our findings corroborate the efficacy of CRT as a therapeutic modality for patients with CHF and a wide QRS complex, particularly in the presence of LBBB [1–5]. It should be noted, however, that there are also patients with other underlying causes of cardiac dyssynchrony. In the present study, the patients in question required constant ventricular stimulation, including pediatric patients. Implantation of the left ventricular electrode via the conventional technique through coronary veins is a well-established and successful procedure. However, it should be noted that this approach does not achieve 100% success in all cases [13, 14, 17, 18]. In the present study, we encountered difficulties in 8.3% of cases, necessitating the use of transseptal (with IVS puncture) and epicardial techniques. It is beyond dispute that CRT has a beneficial impact on life expectancy and quality of life in patients with CHF. It has been demonstrated that approximately 30% of patients do not respond to CRT. This figure has been observed to decline in recent years. Our findings indicate a notable prevalence of these patients (27.8%), which is consistent with the data presented in the existing literature. It is important to note, however, that the higher number of non-responders to CRT was observed in our initial experience between 2012 and 2015 [13, 14, 19]. This can be attributed to two factors: firstly, the development and mastery of the method by our team in recent years; and secondly, the emergence of more advanced devices for CRT, which have numerous innovative features, including a variety of stimulation algorithms that increase its proportion in the patient's heart rhythm. This is of particular significance for patients presenting with episodes of AF with tachysystole, which has the potential to suppress the stimulation. In instances where the aforementioned algorithms and pharmacological agents prove insufficient, an artificial complete atrioventricular heart block is employed to facilitate a complete patient's transition to CRT [3, 4]. In the present study, there were 16 (10.3%) such patients. The aforementioned procedure was reasonable and necessary for patients with CHF and CRT, resulting in a significant improvement in the patient's condition. The automatic optimization of CRT, based on different principles among different manufacturers, allows for the control of effective ventricular (primarily LV) capture in a synchronous

manner with atrial work. This process occurs continuously, both at rest and during exercise, thereby rendering CRT operation more dynamic and efficient [9–11]. Our findings substantiate the indisputable benefit of this functionality, particularly in reducing the number of non-responders to CRT among patients with a CRT device. The introduction of quadripolar electrodes addresses several issues. It has been demonstrated that left ventricular stimulation should be performed from the basal sites, a finding that is corroborated by our own experience. Nevertheless, this is not always feasible with a two-pole electrode, as the optimal fixation of the electrode in the vein necessitates its placement as deeply (distally) as the vein's diameter allows. In such instances, the positioning of the electrode often results in the stimulating poles being situated in close proximity to the apex of the heart, with the stimulation carried out from the apical regions. In the present study, there were 26 (16.7%) such patients, of whom 22 (14.2%) were classified as non-responders to CRT. The utilization of a four-pole electrode promptly resolves this issue, facilitating the implementation of LV stimulation from the poles situated in closer proximity to the basal regions of the heart. Moreover, the utilization of supplementary poles enables the selection of a more optimal stimulation polarity option, taking into account both electrical parameters, such as stimulation threshold and impedance, and the site of depolarization initiation, in consideration of the physiological nature of the propagation of the excitation wave through the myocardium [20, 21]. Furthermore, this permits the potential for transitioning to stimulation from electrodes situated at a greater distance from the diaphragmatic nerve, thus eliminating any potential for diaphragmatic stimulation, should it be present. The advantage of utilizing echocardiography for the periodic optimization of CRT is irrefutable; nevertheless, this is not always a convenient or feasible option within the clinical setting. Consequently, a significant number of investigators have adopted the use of ECG criteria or have resorted to echocardiography when ECG criteria are ineffective. In the process of optimizing CRT under electrocardiographic control, the duration of the QRS complex was previously identified as a critical factor, with the objective of achieving the narrowest possible duration. Nevertheless, over time, our attention was also directed towards the axis deviation. In the majority of cases, narrowing of the QRS complex accompanied by the right axis deviation (i.e., axis verticalization) resulted in positive hemodynamic and clinical effects due to early activation and synchronization of the LV [8, 15, 17, 22]. The utilization of CRT devices with remote monitoring offers a distinct advantage, as it enables the acquisition of vital information regarding patient status and device performance via a website. It is important to note that this function does not necessarily obviate the necessity of a patient's visit to the clinic in all cases. Nevertheless, it can markedly diminish the frequency of such visits.

Figure 3. Kaplan-Meier curves illustrating the survival of patients (as indicated by the decreasing number of patients in) in groups of patients who exhibited a positive response CRT and those who did not



There is a statistically significant discrepancy between the groups with regard to the number of patients.

Conclusion

Resynchronization therapy is an efficacious treatment modality for patients with chronic heart failure and cardiac dyssynchrony. The efficacy of resynchronization therapy is evidenced by an increased life expectancy and an improved quality of life. Not all patients respond to resynchronization therapy. The application of modern devices has the potential to enhance the number of patients who achieve a favorable outcome from resynchronization therapy. The control and optimization of resynchronization therapy represents a fundamental aspect of the methodology. In the process of optimizing resynchronization therapy, electrocardiographic criteria of efficacy may be employed, including the duration of the QRS complex and the changes in the position of the electrical axis of the heart.

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Conflict of interest

The author of the article, N.M. Neminushchy, declares a conflict of interest in connection with conducting educational events for the Medtronic company for a fee.

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