学位論文

Significance of effective cardiac resynchronization therapy pacing for clinical responses: An analysis based on the effective cardiac resynchronization therapy algorithm
(Effective Cardiac Resynchronization Therapy Pacing 率の臨床的意義)

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Significance of effective cardiac resynchronization therapy pacing for clinical responses: an analysis based on effective cardiac resynchronization therapy algorithm

Short title: **Effective CRT pacing and clinical responses**

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Abstract

Background: High percent ventricular pacing (%Vp) maximizes cardiac resynchronization therapy (CRT) response. Effective CRT algorithm classifies each left ventricular (LV) pace as effective or ineffective, based on the detection of QS/QS-r morphology on the electrogram; however, the relationship between percent effective CRT pacing (%e-CRT) and responses is unclear.

Objective: We aimed to clarify the association between %e-CRT and clinical outcomes.

Methods: Among 136 consecutive CRT patients, 49 using adaptive and effective CRT algorithm with %Vp >90% were evaluated. The primary and secondary outcomes were heart failure (HF) hospitalization and prevalence of CRT responders – defined as patients with improvement in LV ejection fraction ≥10% or a reduction in LV end-systolic volume ≥15% after CRT implantation, respectively.

Results: We divided the patients into the effective group (n=25) and the less-effective group (n=24) by the median value of %e-CRT (97.4%). During the median follow-up period of 507 days (interquartile, 335–730), the effective group had a significantly lower risk of HF hospitalization than the less-effective group as revealed by Kaplan–Meier analysis (log-rank: p=0.016). Univariate analysis revealed %e-CRT ≥97.4% (hazard ratio, 0.12; 95% confidence

interval [CI], 0.01–0.95; p=0.045) as a predictor of HF hospitalization. The effective group had a higher prevalence of CRT responders than the less-effective group (23 [92%] vs. 9 [38%], p<0.001). Univariate analysis revealed that %e-CRT ≥97.4% (odds ratio, 19.20; 95% CI, 3.63–101.00; p<0.001) was a predictor of CRT response.

Conclusion: High %e-CRT is associated with high CRT responder prevalence and low HF hospitalization risk.

Keywords

Heart failure, cardiac resynchronization therapy, effective pacing, biventricular pacing, QRS duration, atrial fibrillation

Introduction

Cardiac resynchronization therapy (CRT) is an established treatment for patients with left ventricular (LV) dysfunction and wide QRS duration[1-3]; however, approximately one-third of patients do not respond to CRT[4]. In addition to the clinical factors, device-related factors such as insufficient percent ventricular pacing (%Vp), suboptimal LV lead location position, and suboptimal atrioventricular (AV) and ventricle-ventricular (VV) timing are associated with CRT response[5]. Studies have reported a relationship between %Vp and reduction of heart failure (HF); higher %Vp was associated with increased CRT responders and decreased risk of poor prognosis[6, 7]. However, %Vp overestimates the degree of effective biventricular (BiV) pacing due to pseudo-fusion, inactivation of the ventricular myocardium, loss of capture, and LV conduction latency[8, 9]. Therefore, evaluating the effectiveness of pacing in ventricular myocardium activation is important, while simultaneously assessing the possibility of achieving %Vp close to 100%.

Effective CRT algorithm (Medtronic Inc., Minneapolis, MN, USA) can quantify LV pacing using beat-to-beat analysis of the paced morphology of an electrogram (EGM)[9-11]. This algorithm is based on a fundamental electrophysiological concept in which an initial negative deflection (QS/QS-r morphology, Figure 1) is registered in the LV tip (pacing site)-right ventricular (RV) coil EGM if the pace effectively captures the LV myocardium[12]. OLÉ CRT study showed that the

average %Vp significantly overestimated percent effective CRT pacing (%e-CRT), and 18% of CRT recipients had over 3% of ineffective pacing using this EGM-based algorithm.[9] This algorithm revealed suboptimal LV pacing and potential reasons for insufficient response and therefore, could help CRT pacing optimization.

Little is known about the association between %e-CRT and clinical CRT benefits. Therefore, we aimed to clarify whether %e-CRT is associated with clinical outcomes.

Methods

Study population

We initially identified 136 consecutive patients with HF who were treated with CRT devices between January 2018 and December 2020 at the National Cerebral and Cardiovascular Center, Suita, Japan. The inclusion criteria were as follows: (1) New York Heart Association (NYHA) functional class II-IV, (2) left ventricular ejection fraction ≤35%, and (3) QRS duration ≥120 msec[13]. The exclusion criteria were as follows: (1) CRT devices incapable of implementing the effective CRT algorithm (n=63), (2) drop out (n=2), (3) adaptive CRT (aCRT) (Medtronic Inc., Minneapolis, MN, USA) algorithm not used to match the method of optimization (n=21)[11], and

92 (4) cumulative %Vp less than 90% (n=1)[7, 8]. After the exclusion, 49 patients were enrolled
93 (Figure 2).
94 This study was approved by the Institutional Research Board of the National Cerebral and
95 Cardiovascular Center, Suita, Japan (M26-150-13), and conducted with adherence to the
96 Declaration of Helsinki. All patients provided written informed consent before undergoing CRT
97 device implantation.
98
99 **Clinical characteristics**
100 Clinical data, including age, sex, underlying heart disease, comorbidities, medication,
101 echocardiographic parameters, and 12-lead electrocardiogram, were collected from medical
102 records.
103
104 **CRT implantation and Adaptive CRT algorithm**
105 The CRT device was implanted transvenously. An RV lead was positioned at the RV septum
106 or septal apex, and a quadripolar LV lead was implanted in a suitable branch of the coronary vein
107 at a site that produced an acceptable pacing threshold without phrenic nerve stimulation.

AV and VV delay optimization was automatically performed using the aCRT algorithm[14]. In brief, if the conduction interval from the right atrium to the RV is normal, the algorithm provides LV-only pacing synchronized with RV activation. Conversely, if the intrinsic AV conduction interval is prolonged, the algorithm provides a BiV pacing.

Effective CRT algorithm

The effective CRT algorithm automatically quantifies 100 acquired ventricular events every hour 25 minutes after the hour, in an intermittent manner, and classifies ventricular pacing as effective or ineffective based on specific morphological features on a 164 msec window of the LV tip to RV coil EGM[12]. When effective pacing occurs, EGMs are broadly characterized by a negative deflection (QS or QS-r morphology) followed by slight positive deflection (Figure 1); this represents the local capture at the LV pacing site, regardless of the BiV- or LV-only pacing mode. Parenthetically, LV pacing in response to premature RV sensing, called Ventricular Sense Response, was not treated as paced beats but as sensed beats for analysis.

Percent effective and ineffective CRT and ventricular pacing

Percentage of various types of CRT pacing were calculated as follows:

%e-CRT = (effective CRT pacing / [effective CRT pacing + ineffective CRT pacing + ventricular sense response + Sensing]) × 100 [%]

Percent ineffective CRT pacing (%i-CRT) = (ineffective CRT pacing / [effective CRT pacing + ineffective CRT pacing + ventricular sense response + sensing]) × 100 [%]

%Vp = (ventricular pacing / [ventricular pacing + ventricular sense response + sensing]) × 100 [%]

All variables were measured throughout the follow-up period, and the average cumulative %e-CRT, %i-CRT and %Vp were calculated. The patients were divided into an effective CRT group and a less-effective CRT group based on the median value of %e-CRT.

For patients with atrial fibrillation (AF) documented within the follow-up period, %Vp, %e-CRT, and %i-CRT during AF episodes were also calculated.

Clinical outcomes

The primary and secondary outcomes were hospitalization for HF and the prevalence of CRT responders, respectively. Cardiac contractile function was assessed before and 6 months after CRT device implantation during a stable hemodynamic state. CRT responders were defined as patients with an improvement in left ventricular ejection fraction (LVEF) ≥10% or a reduction in

left ventricular end-systolic volume (LVESV) ≥15% compared to baseline at 6 months post-implantation.

Statistical analysis

Normally distributed continuous variables are expressed as means and standard deviations. The Kolmogorov–Smirnov test was used to detect variables that were not distributed normally; they are expressed as medians and interquartile ranges. Student's *t*-test or Mann–Whitney U test was used to compare differences between the two distribution groups where appropriate. Categorical variables were compared using Fisher's exact test. Univariate analysis was performed using a Cox regression or logistic regression model to determine predictors where appropriate. All statistical tests were two-tailed, and values of $p < 0.05$ were considered significant. All statistical analyses were performed using SPSS Statistics software version 28 (IBM Corporation, Armonk, NY, USA).

Results

Baseline characteristics

158 Forty-nine patients (37 males, mean age 64.0 ± 13.3 years) were enrolled in the present study.
159 The median of %e-CRT was 97.4%; the patients in this cohort were divided into the effective
160 CRT group (%e-CRT ≥97.4%, n=25) or the less-effective CRT group (%e-CRT <97.4%, n=24).
161 There were no significant differences between the groups' baseline characteristics (Table 1).
162
163 **Discrepancy between percent effective CRT pacing and ventricular pacing**
164 The cumulative value of %e-CRT, %i-CRT, and %Vp during the follow-up are presented in
165 Table 1. In this study population, the median %Vp and %i-CRT (= %Vp – %e-CRT) values were
166 97.8% and 0.3%, respectively. The scatter plot (Figure 3) shows that all patients had over 90%
167 ventricular pacing. In five patients, there was a difference of 3% or more between %Vp and %e-
168 CRT[9], and their median %Vp, %e-CRT, and %i-CRT were 97.0 [95.9–97.1] %, 63.4 [32.2–
169 77.8] %, and 33.7 [15.1–63.7] %, respectively.
170 AF was documented in 12 patients during the follow-up period. There was no significant
171 difference in the percentage of patients with atrial fibrillation (AF) between the two groups,
172 despite a trend toward a higher percentage in the less-effective CRT group (3 [12.0%] vs. 9
173 [37.5%], p=0.051). Among these 12 AF documented patients with a mean AF burden of 3.3 ±
174 7.8%, median cumulative %Vp, %e-CRT, and %i-CRT were 96.3 [93.6–98.3%] (during AF: 87.6

175 [83.1–97.6] %), 95.6 [92.1–97.4] % (during AF: 86.2 [80.5– 97.6] %), and 0.6 [0.4–1.0] % (during
176 AF: 0.7 [0.1–1.6] %), respectively.
177
178 **HF hospitalization**
179 During the median follow-up period of 507 [335–730] days, nine (18%; effective group: 1
180 [4%] vs. less-effective group: 8 [33%]) patients experienced HF hospitalization. According to
181 Kaplan–Meier analysis, the effective CRT group had a significantly lower risk of HF
182 hospitalization (log-rank, p=0.016, Figure 4A); however, there was no significant difference in
183 the Kaplan–Meier curve for the cumulative incidence of HF hospitalization between the groups
184 divided by the median value of %Vp, 97.8% (log-rank, p=0.11, Figure 4B). Univariate analysis
185 revealed that ischemic cardiomyopathy (hazard ratio, 4.80; 95% confidence interval [CI], 1.27–
186 18.13; p=0.021) and %e-CRT ≥97.4% (hazard ratio, 0.12; 95% CI, 0.01–0.95; p=0.045) were
187 predictors of HF hospitalization (Table 2).
188
189 **CRT responders**
190 The effective CRT group had a higher prevalence of CRT responders than the less-effective
191 CRT group (23 [92%] vs. 9 [38%]; Figure 5). The median total %e-CRT (97.4%) predicted CRT

response with 71.9% sensitivity, 88.9% specificity, 92.4% positive predictive value, and 62.7% negative predictive value. Conversely, the median total %Vp (97.8%) predicted CRT response with 66% sensitivity, 78% specificity, 85% positive predictive value, and 55% negative predictive value. Univariate analysis revealed that QRS duration ≥150 msec (odds ratio, 4.69; 95% CI, 1.33–16.50; p=0.016), %Vp ≥97.8% (odds ratio, 6.20; 95% CI, 1.63–23.60; p=0.007) and %e-CRT ≥97.4% (odds ratio, 19.20; 95% CI, 3.63–101.00; p<0.001) were predictors of CRT responders (Table 3).

Discussion

Main findings

This study evaluated the relationship between clinical outcomes and %e-CRT. Significant findings of this study are as follows: (1) patients with high %e-CRT have a low risk of HF hospitalization, (2) low %e-CRT is a predictor of HF hospitalization, and (3) high %e-CRT is a predictor of CRT response.

Effective CRT algorithm for evaluation of effective pacing

%Vp overestimates the degree of effective pacing. Kamath et al. evaluated the association between effective pacing and CRT response using a 12-lead Holter monitor in patients with permanent AF and CRT devices[8]. Only 76% of the beats were fully paced with complete capture, and 40% of pacing accounted for fusion and pseudo-fusion beats in patients with ineffective pacing, defined as ≤90% fully paced beats with complete capture of the heart. Ghosh et al. developed a device-based automatic algorithm using morphological features of an EGM, which defined effective pacing as a negative deflection (QS or QS-r morphology); the algorithm accurately classified 98.2% effective LV pacing beats, 75.8% pseudo-fusion beats, and 100% beats with loss of LV capture compared to an ECG-based classification truth[12]. The utility and superiority of the algorithm is evident particularly in discriminating loss of capture completely. In addition, the OLÉ CRT study showed that the average %Vp significantly overestimated %e-CRT pacing by 7% on average[9]; therefore, effective pacing should be evaluated to assess its efficiency in activating LV myocardium. Effective CRT algorithm can be utilized in the assessment.

Effective CRT and CRT response

Effective delivery of BiV pacing determines the success of CRT and response. In a large cohort analyzed in the ALTITUDE study, increased percentages of BiV pacing were associated with significant mortality reduction[6]. Furthermore, Ruwald et al. reported that BiV pacing exceeding 90% was associated with CRT mortality benefit[7]. Moreover, among the CRT patients with high %Vp (>90%), ineffective pacing was associated with CRT nonresponders[8]. The presence of more than 90% of fully paced beats correlated with improvement in NYHA. In our study, patients with high %e-CRT (≥97.4%) had a lower risk of HF hospitalization, although there was no significant difference between patients with high and low %Vp (97.8%). Univariate analysis revealed that high %e-CRT (≥97.4%) resulted in risk reduction for HF hospitalization. In addition, high %e-CRT correlated with CRT response and was a predictor of CRT response. The cohort in this study had a cumulative %Vp of over 90%; however, five patients (10.2%) had %i-CRT ≥3%. These patients had poor clinical outcomes; four were CRT nonresponders, and three experienced HF hospitalization during the follow-up period. An effective CRT algorithm is important in predicting clinical and CRT responses.

Clinical implication

Effective CRT algorithm can efficiently address hidden issues, consequently optimizing CRT delivery. OLÉ CRT study identified causes of high %i-CRT as, latency, variable AV conduction which induces pseudo-fusion, and loss of capture[9]; these potential reasons[5,15] are responsible for suboptimal response to CRT and could be the management target for nonresponders[16, 17]. Specific manual device programming, including continuous optimization algorithm (aCRT)[11], VV delay optimization[18], high output pacing[19], and LV cathode change, may be alternative methods to resolve these problems. In this study, all patients used the aCRT algorithm; however, five patients (10.2%) exhibited a discrepancy in the association between %e-CRT and %Vp (>3%). Further prospective studies are needed to evaluate the efficiency of specific manual device programming strategies that optimize %e-CRT and clinical outcomes in these patients. Our findings suggest that a higher cumulative %e-CRT was associated with a lower risk of HF hospitalization and a higher prevalence of CRT responders. At this point, it is difficult to identify the optimal cut off value of %e-CRT because %e-CRT showed a large variability and the lower %e-CRT does not affect the lower efficacy of CRT linearly. The median value could stratify the risk of HF and CRT response in this study cohort; it is notable that 'lower %e-CRT compared to %Vp' is associated with the risk of HF and non-response to CRT, not the %e-CRT value itself.

256 Therefore, effectuating a nearly 100% ventricular and effective CRT pacing could be the goal of
257 pacing management.
258
259 **Study limitation**
260 First, this was a single-center retrospective study. The relatively small sample size was a
261 limitation of this study.
262 Second, the effective CRT algorithm evaluates only the LV EGM morphology. Even if the
263 EGM shows an effective morphology, the magnitude of LV capture by pacing could be less in
264 some cases than others due to scar burden. Thus, although an excellent diagnostic capability has
265 been reported[12], there is a possibility that this algorithm could overestimate the true %e-CRT.
266 Third, patients with a cumulative %Vp <90%[7, 8] and not using the aCRT algorithm[11] were
267 excluded. Though there was no optimal cut-off value of percent biventricular pacing, a previous
268 study showed that biventricular pacing >90% was associated with a benefit of CRT[7]. Hence,
269 highly effective cases of CRT could be selected[6, 7, 11, 20]. However, even in such a population,
270 patients with lower %e-CRT had worse outcomes; thus %e-CRT would help detect potential CRT
271 nonresponders.

Finally, it is unknown whether this novel marker can be applied in the treatment of CRT nonresponders. Further studies are required to address these problems.

Conclusions

Relatively higher effective CRT pacing percentage was associated with a higher prevalence of CRT responders and a lower risk of hospitalization for HF. The effective CRT pacing percentage could be a guide for optimal CRT delivery.

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293

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Tables

Table 1 Baseline characteristics and pacing details

	Total (n=49)	Effective group (%e-CRT ≥ 97.4%, n=25)	Less effective group (%e-CRT < 97.4%, n=24)	P value
Baseline characteristics				
Age [years]	64.0 ± 13.3	64.8 ± 12.1	63.1 ± 14.7	0.67
Male gender [(%)]	37 (75.5)	18 (72.0)	19 (79.2)	0.74
Ischemic cardiomyopathy [(%)]	13 (26.5)	7 (28.0)	6 (25.0)	0.99
Chronic kidney disease [(%)]	22 (44.9)	12 (48.0)	10 (41.7)	0.78
Left bundle branch block [(%)]	15 (30.6)	9 (36.0)	6 (25.0)	0.54
QRS duration [msec]	157.0 ± 27.0	160.3 ± 27.6	153.6 ± 26.5	0.39
History of atrial arrhythmias	15 (30.6)	7 (28.0)	8 (33.3)	0.76
NYHA class III/IV [(%)]	16 (32.7)	8 (32.0)	8 (33.3)	0.99
BNP [pg/mL]	221.9 [101.2 – 448.5]	187.8 [76.4 – 251.3]	304.9 [126.6 – 671.1]	0.067
LVEF [%]	24.6 ± 7.4	25.7 ± 7.5	23.4 ± 7.3	0.28
LVESV [mL]	163.8 ± 87.5	143.2 ± 56.7	185.3 ± 108.2	0.099
CRTD [(%)]	44 (89.8)	21 (84.0)	23 (95.8)	0.35

Secondary prevention [(%)]	9 (18.4)	7 (28.0)	2 (8.2)	0.14
Pacing details during follow-up				
%Vp [%] *	97.8 [96.1 – 98.4]	98.4 [98.1 – 99.3]	96.0 [93.6 – 97.1]	<0.001
Bi-ventricular pace [%]	54.2 ± 44.0	61.0 ± 42.8	47.1 ± 44.9	0.28
Left ventricular pace [%]	45.6 ± 44.1	38.9 ± 42.9	52.7 ± 45.1	0.28
%e-CRT [%] *	97.4 [93.7 – 98.3]	98.3 [97.9 – 99.0]	93.7 [89.8 – 96.2]	<0.001
%i-CRT [%] *	0.3 [0 – 0.8]	0.1 [0 – 0.2]	0.7 [0.3 – 1.8]	<0.001
Atrial fibrillation document [(%)]	12 (24.5)	3 (12.0)	9 (37.5)	0.051

Data are means ± standard deviations for normally distributed data, and medians and interquartile ranges for non-normally distributed data, or n (%). All statistical tests were 2-tailed, and $p<0.05$ was considered significant (*).

Abbreviations

NYHA, New York Heart Association; BNP, brain natriuretic peptide; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; CRTD, cardiac resynchronization therapy defibrillator; %Vp, percent ventricular pacing; %e-CRT, percent effective cardiac resynchronization therapy pacing; %i-CRT, percent ineffective cardiac resynchronization therapy pacing

Table 2 Univariate analysis with a Cox regression model for heart failure hospitalization

	Univariate analysis		
Variables	**Hazard ratio**	**95% confidence index**	**P value**
Age	0.99	0.94 – 1.04	0.76
Male sex	2.11	0.26 – 17.09	0.48
Ischemic cardiomyopathy *	4.80	1.27 – 18.13	0.021
Chronic kidney disease	3.09	0.77 – 12.51	0.11
History of atrial arrhythmias	0.83	0.21 – 3.35	0.80
LVEF (1% increase)	0.90	0.80 – 1.00	0.059
Left bundle branch block	0.88	0.22 – 3.54	0.86
QRS duration ≥ 150 msec	0.26	0.07 – 1.06	0.060
%Vp ≥ 97.8%	0.30	0.06 – 1.46	0.14
%e-CRT ≥ 97.4% *	0.12	0.01 – 0.95	0.045
Atrial fibrillation document	0.64	0.13 – 3.11	0.58

All statistical tests were 2-tailed, and $p<0.05$ was considered significant (*).

Abbreviations

LVEF, left ventricular ejection fraction; %Vp, percent ventricular pacing; %e-CRT, percent effective cardiac resynchronization therapy pacing

Table 3 Univariate analysis with a logistic regression model for CRT response

	Univariate analysis		
Variables	**Odds ratio**	**95% confidence index**	**P value**
Age	1.05	1.00 – 1.10	0.052
Male sex	0.29	0.06 – 1.53	0.15
Ischemic cardiomyopathy	1.27	0.33 – 4.96	0.73
Chronic kidney disease	1.83	0.55 – 6.16	0.33
History of atrial arrhythmias	0.72	0.20 – 2.52	0.61
LVEF (1% increase)	1.03	0.94 – 1.11	0.56
Left bundle branch block	1.70	0.45 – 6.48	0.44
QRS duration ≥ 150 msec *	4.69	1.33 – 16.50	0.016
%Vp ≥ 97.8% *	6.20	1.63 – 23.60	0.007
%e-CRT ≥ 97.4% *	19.20	3.63 – 101.00	<0.001
Atrial fibrillation document	0.28	0.66 – 1.22	0.090

All statistical tests were 2-tailed, and $p<0.05$ was considered significant (*).

Abbreviations

LVEF, left ventricular ejection fraction; %Vp, percent ventricular pacing; %e-CRT, percent effective cardiac resynchronization therapy pacing

Figure captions

Fig. 1 Definition of effective cardiac resynchronization therapy pacing

Based on the left ventricular (LV) tip-right ventricular (RV) coil electrocardiogram (EGM), the following criteria for effective LV pacing were established: (1) baseline amplitude, which is defined as the EGM amplitude at the time pacing was delivered; (2) minimum amplitude (Min) and timing of the minimum amplitude (Tmin) measured from the time at which pace is delivered; (3) maximum amplitude (Max) and timing of the maximum amplitude (Tmax) measured from the time at which the pace is delivered. Tmin must occur at least 23 ms before Tmax, and the ratio of the magnitudes of Max minus baseline and baseline minus Min must be between 0.125 and 8. In addition, the magnitudes of Max must exceed the baseline, and Max minus Min must be over 1.6 mV. Any beat that does not meet these effective pacing criteria is treated as ineffective.

Fig. 2 Flow chart of the patients included in the analyses

The flow diagram shows the recruitment and analysis process of this study.

Abbreviations: CRTD, cardiac resynchronization therapy; %Vp, percent ventricular pacing; %e-CRT, percent effective cardiac resynchronization therapy pacing

Fig. 3 Scatter plot of percent effective cardiac resynchronization therapy pacing (%e-CRT) vs. percent ventricular pacing (%Vp) for each patient

The black and red dotted lines show the cut-off %Vp value of the inclusion criteria (90%) and the median value of %e-CRT (97.4%) in this cohort, respectively. Patients with a discrepancy between %e-CRT and %Vp, defined as %i-CRT ≥3%, are indicated by red marks.

Fig. 4 Heart failure (HF) hospitalization

The cumulative incidence of HF hospitalization using the Kaplan–Meier estimates is presented.

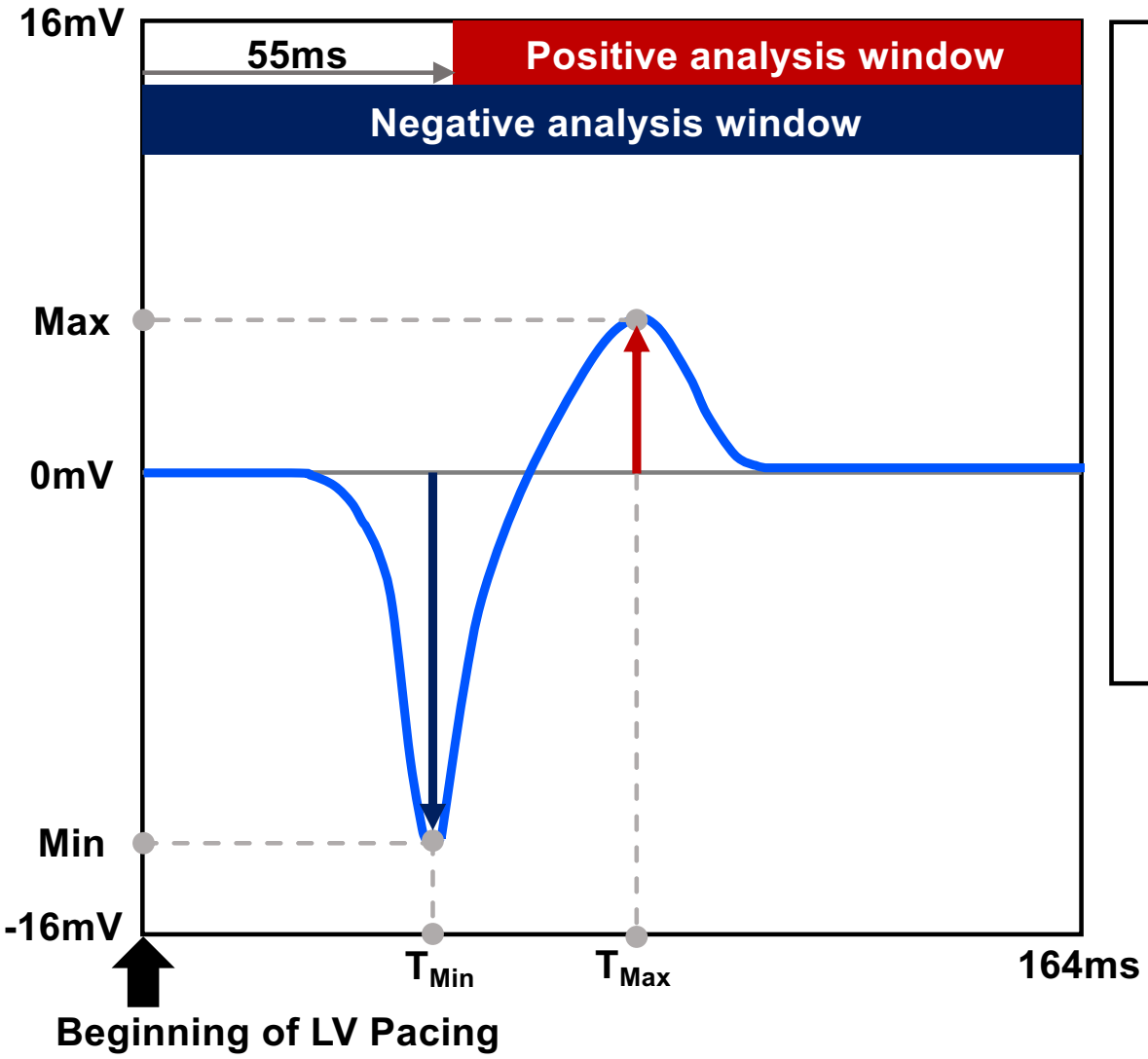
A: Groups divided by the median value of percent effective cardiac resynchronization therapy pacing (%e-CRT)

B: Groups divided by the median value of percent ventricular pacing (%Vp)

Fig. 5 Cardiac resynchronization therapy (CRT) responder percentage

Comparisons of CRT responder percentage between groups divided by median values of (A) percent effective CRT pacing (%e-CRT) and (B) percent ventricular pacing (%Vp).

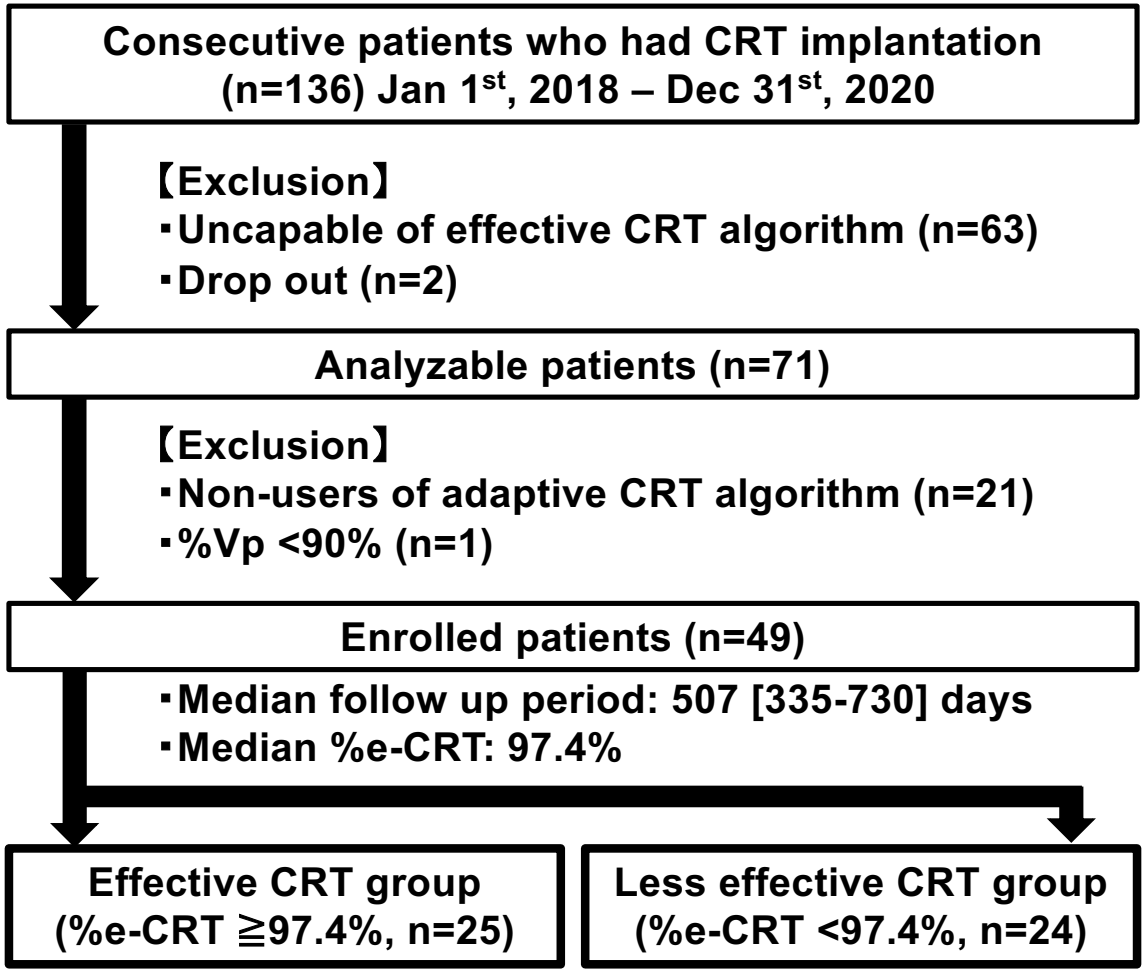
Electrogram of LV tip (pacing site)−RV coil

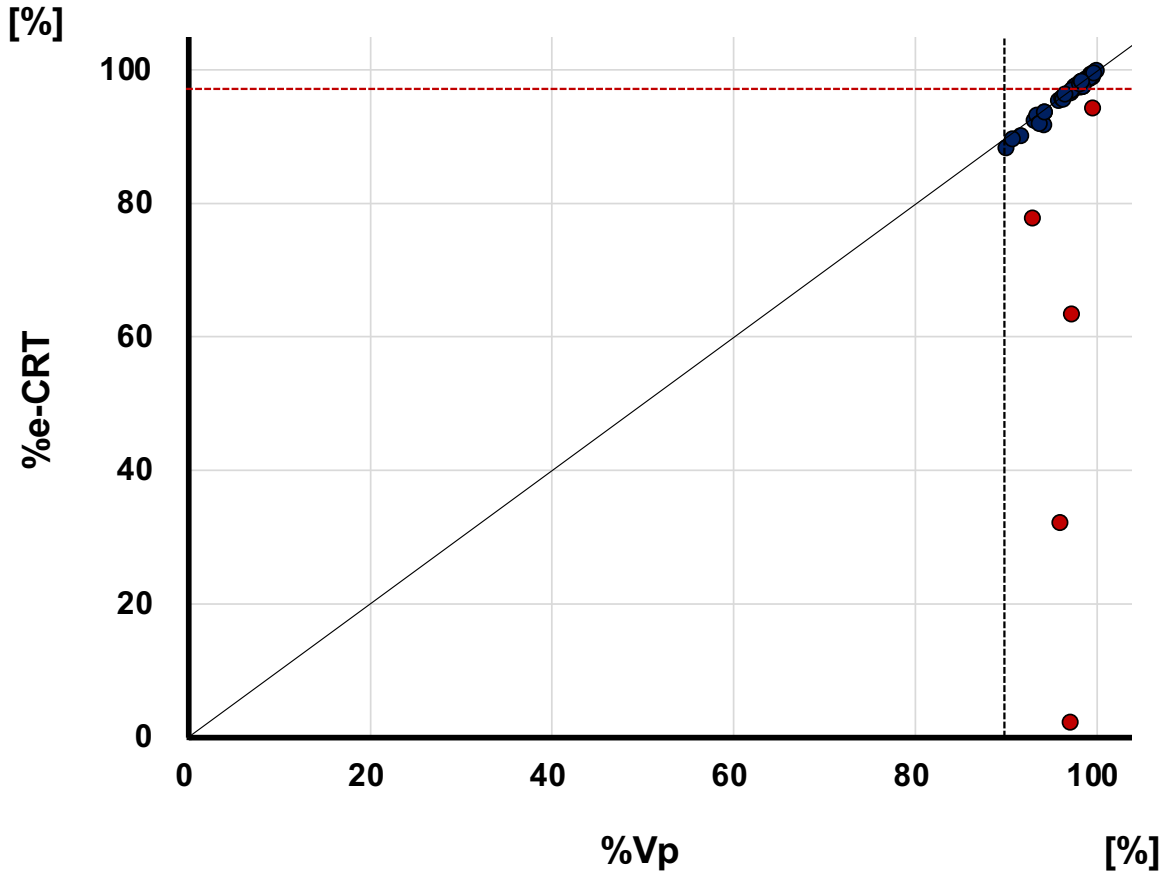


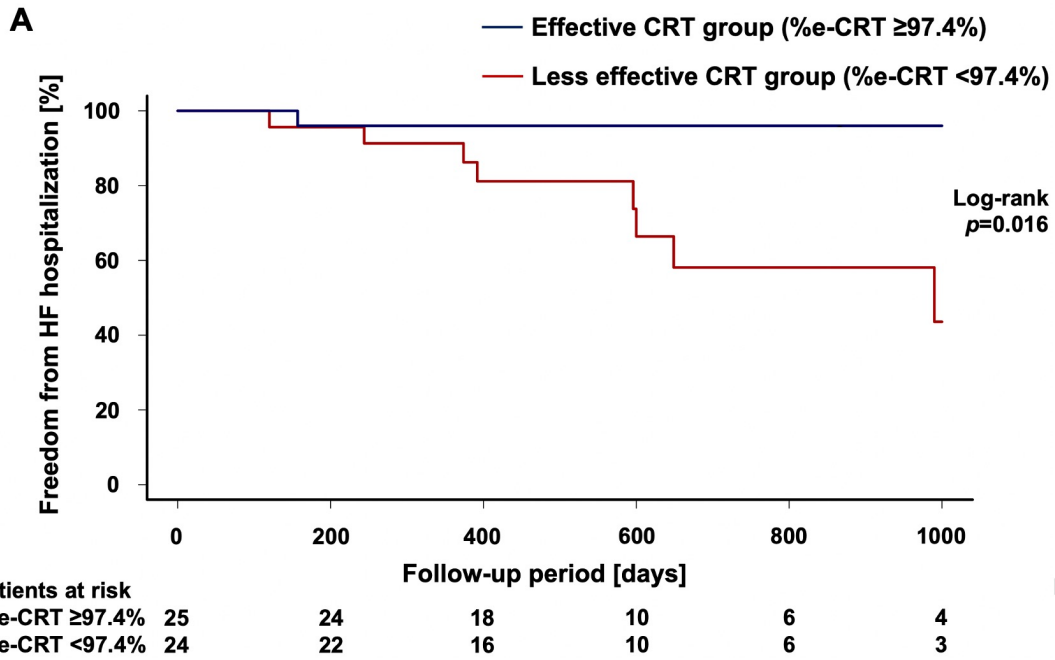
【Effective pacing definition】

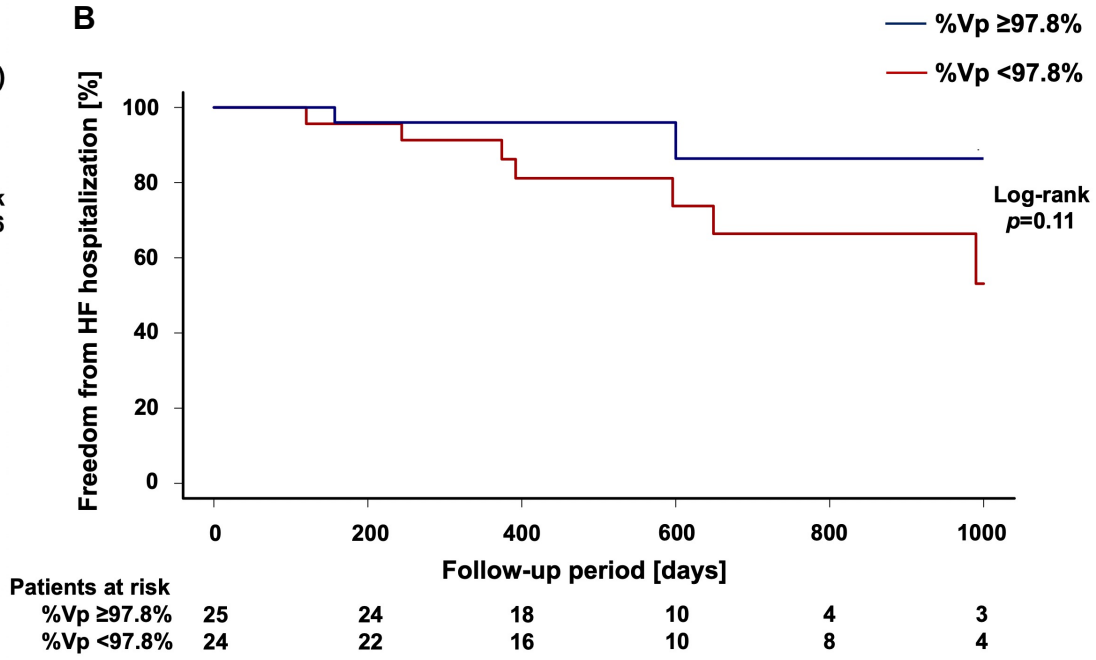
- $T_{Max} - T_{Min} \geq 23ms$
- $0.125 \leq |Max| / |Min| < 8.0$
- Max > baseline
- Max − Min ≥ 1.6mV

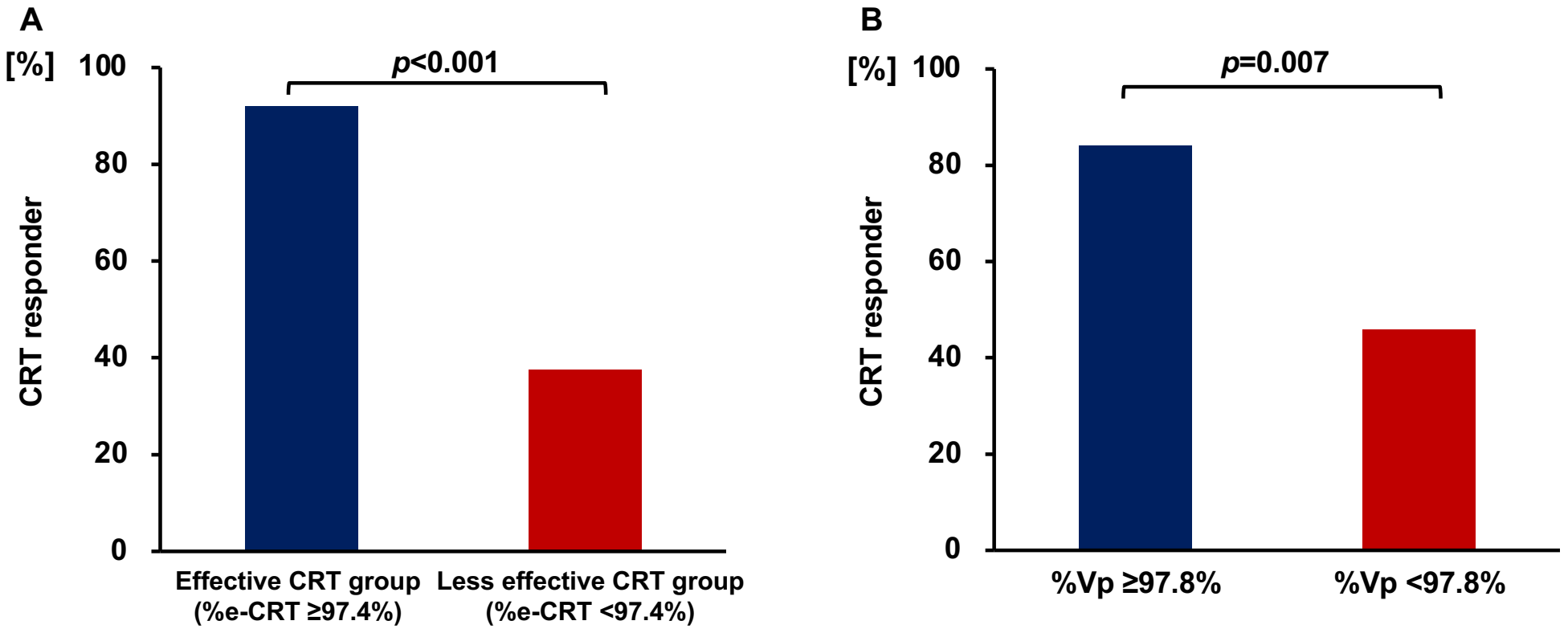
QS/QS-r morphology


Consecutive patients who had CRT implantation
(n=136) Jan 1st, 2018 – Dec 31st, 2020
【Exclusion】
・Uncapable of effective CRT algorithm (n=63)
・Drop out (n=2)
Analyzable patients (n=71)
【Exclusion】
・Non-users of adaptive CRT algorithm (n=21)
・%Vp <90% (n=1)
Enrolled patients (n=49)
・Median follow up period: 507 [335-730] days
・Median %e-CRT: 97.4%
Effective CRT group
(%e-CRT ≧97.4%, n=25)
Less effective CRT group
(%e-CRT <97.4%, n=24)


[%]
100
80
60
40
20
0
%e-CRT
0
20
40
60
80
100
%Vp
[%]


A
Effective CRT group (%e-CRT ≥97.4%)
Less effective CRT group (%e-CRT <97.4%)
Freedom from HF hospitalization [%]
100
80
60
40
20
0
Log-rank
p=0.016
0
200
400
600
800
1000
Follow-up period [days]
Patients at risk
%e-CRT ≥97.4% 25 24 18 10 6 4
%e-CRT <97.4% 24 22 16 10 6 3


B
%Vp ≥97.8%
%Vp <97.8%
Freedom from HF hospitalization [%]
100
80
60
40
20
0
Log-rank
p=0.11
0
200
400
600
800
1000
Follow-up period [days]
Patients at risk
%Vp ≥97.8% 25 24 18 10 4 3
%Vp <97.8% 24 22 16 10 8 4


A
[%]
100
80
60
40
20
0
CRT responder
p<0.001
Effective CRT group
(%e-CRT ≥97.4%)
Less effective CRT group
(%e-CRT <97.4%)
B
[%]
100
80
60
40
20
0
CRT responder
p=0.007
%Vp ≥97.8%
%Vp <97.8%