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ORIGINAL ARTICLE

Propensity-score matched comparison of renal and neurohormonal effects of catheter ablation for frequent premature ventricular contractions in patients with and without systolic dysfunction

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Abstract

Background: Catheter ablation (CA) for premature ventricular contractions (PVCs) restores cardiac and renal functions in patients with reduced left ventricular ejection fraction (LVEF); however, its effects on preserved EF remain unelucidated.

Methods: The study cohort comprised 246 patients with a PVC burden of >10% on Holter electrocardiography. Using propensity matching, we compared the changes in B-type natriuretic peptide (BNP) levels and estimated glomerular filtration rate (eGFR) in patients who underwent CA or did not.

Results: Postoperative BNP levels were decreased significantly in the CA group, regardless of the degree of LVEF, whereas there was no change in those of the non-CA group. Among patients who underwent CA, BNP levels decreased from 44.1 to 33.0 pg/mL in those with LVEF ≥50% ($p = .002$) and from 141.0 to 87.9 pg/mL in those with LVEF <50% ($p < .001$). Regarding eGFR, postoperative eGFR was significantly improved in the CA group of patients with LVEF ≥50% (from 71.4 to 74.7 mL/min/1.73 m^2, $p = .006$), whereas it decreased in the non-CA group. A similar trend was observed in the group with a reduced LVEF. Adjusted for propensity score matching, there was a significant decrease in the BNP level and recovery of eGFR after CA in patients with LVEF >50%.

Conclusions: This study showed that CA for frequent PVCs decreases BNP levels and increases eGFR even in patients with preserved LVEF.

KEYWORDS

B-type natriuretic peptide, catheter ablation, estimated glomerular filtration rate, premature ventricular contractions, ventricular ejection fraction

1 | INTRODUCTION

Premature ventricular contraction (PVC) is the most common type of ventricular arrhythmia and is considered benign without an underlying cardiac disease. However, the presence of PVC decreases cardiac output,[1] and frequent PVCs can cause PVC-induced cardiomyopathy (PIC), a reversible systolic dysfunction.[2] PIC occurs in patients with a high PVC frequency, with a total daily PVC count beyond 10000,[3] or a PVC burden >10% of the total daily heartbeats (THBs).[4]

In symptomatic PVCs or frequent PVCs with a burden of >10% of the THB, treatment with pharmacotherapy or catheter ablation (CA) is considered.[5] Randomized controlled trials have shown that CA is superior for right ventricular outflow tract (RVOT) origin PVCs to pharmacotherapy in reducing PVC burden, and CA for PVCs from other origins is reportedly effective in eliminating symptoms.[6]

Arrhythmia and renal function reportedly interact, particularly in atrial fibrillation (AF). The presence of AF could worsen renal function, while CA for AF could prevent or reverse the negative effect of AF.[7] A similar phenomenon has been reported for PIC. CA for PIC can improve left ventricular ejection fraction (LVEF) and estimated glomerular filtration rate (eGFR).[8] However, the effect of CA on frequent PVCs in patients with a preserved LVEF remains unknown.

In this study, we evaluated the effect of CA on frequent PVCs by comparing changes in brain natriuretic peptide (BNP) levels and eGFR between patients who underwent CA and those who received noninvasive pharmacotherapy.

To estimate the interaction of CA effectiveness and LVEF, those comparisons were performed in patients with preserved (≥ 50%) and reduced (< 50%) LVEFs separately.

2 | METHODS

2.1 | Study population

This retrospective single-center observational study involved examining 308 consecutive patients with a PVC burden of >10% on 24-h Holter electrocardiograms (ECGs), which were performed between January 2014 and December 2021 at Kameda Medical Center. Of these patients, 246 (133 ablation cases) who underwent blood tests at the baseline and during the 1–6 months of follow-up were enrolled. The indications for CA were determined according to the guidelines of the Japanese Circulation Society.[5] Patients younger than 18 years who underwent hemodialysis or peritoneal dialysis were excluded from this study. The present study also excluded cases of macro-reentrant or sustained ventricular tachycardia (VT). The treatment method was decided after a thorough explanation and discussion between the physician and the patient. Our study protocol complied with the guidelines stipulated in the Declaration of Helsinki and the Japanese Ethical Guidelines for Medical and Health Research involving Human Subjects and was approved by the institutional review boards of the participating institutions.

2.2 | Evaluated parameters

The THB, total PVC count, and PVC burden on Holter ECG were evaluated for all patients. Similarly, the Holter ECG at follow-up, which was mostly scheduled at 1–3 months after CA, was evaluated in the CA group.

Serum BNP and creatinine levels were evaluated using blood tests. Based on the serum creatinine level, eGFR was calculated using the Japanese Society of Nephrology formula.

Patients with eGFR <60 mL/min/1.73 cm^2 were defined as having a chronic kidney disease (CKD) < 60 mL/min/1. The baseline systolic performance and left ventricular diameter were measured using echocardiography. We defined patients with a LVEF of <50% as belonging to the systolic dysfunction group.

Information from medical records was used to determine the presence or absence of structural heart disease, hypertension, coronary artery disease, stroke, cardiac surgery, cardiac implantable devices, and antiarrhythmic drugs.

2.3 | CA and noninvasive therapy

Before the electrophysiological study and CA, antiarrhythmic drugs were discontinued if they were at least five times longer than the half-life period of the drugs. The site of origin of the PVCs was estimated using a 12-lead electrocardiogram. Local anesthesia with sedatives was used to perform the procedure. Vascular access was primarily from the femoral vein, and trans-septal or trans-aortic approaches were performed as needed. A 3D electroanatomical mapping system (CARTO, Biosense Webster Inc., Diamond Bar, CA, USA, or NavX, Abbott, St. Paul, MN, USA) with a multipolar electrode catheter and pace map was used to determine the site of origin. We performed CA through radiofrequency using an irrigation tip catheter. The acute therapeutic effect of ablation was evaluated with a waiting period of at least 15 min after ablation, followed by isoproterenol administration and/or programmed electrical stimulation to assess inducibility. Immediate success was defined as the complete suppression or lack of inducibility of the targeted PVCs during the procedure. Similarly, we defined partial success as an overall reduction without elimination of treated PVCs and failure as not achieving a reduction. In the noninvasive treatment group, antiarrhythmic drugs were used at the discretion of the treating physicians.

2.4 | Follow-up and outcomes

The baseline blood test was the one at the time of initial Holter ECG in the non-CA group, and at the time just before CA in the CA group. The follow-up blood test was performed 1–6 months after the baseline blood test at the discretion of the treating physician. Furthermore, we examined the occurrence of major cardiac and cerebral events (MACCE) 12 months after the CA in CA group, and

12 months after the initial Holter ECG in non-CA group based on medical records. MACCE was defined as all-cause death, hospitalization for heart failure, myocardial infarction, stroke or transient ischemic attack, VT or fibrillation (VF), or the appropriate therapy of implantable cardioverter defibrillator (ICD).

2.5 | Statistical analyses

Continuous variables are presented as mean ± standard deviation or median (interquartile range). All categorical variables were presented as numbers and percentages for each group. Student's *t*-test was used for continuous parametric variables, and the Mann–Whitney *U*-test for continuous nonparametric variables was used for between-group comparisons. The normality of distribution was assessed using the Kolmogorov–Smirnov test. Correlation analyses were performed by calculating nonparametric Spearman's correlation coefficients. Propensity matching was used to adjust the baseline for the invasive and noninvasive treatment groups, EF ≥50% and <50% cases, separately. For this adjustment, propensity scores were calculated by fitting a logistic regression model with confounding factors, with *p*-values of <.05 in the baseline characteristic analyses. Based on the scores, we performed a 1:1 optimal match with a ±0.03 caliper and no replacement; covariate balance was assessed via standardized differences. All *p*-values were two-sided. A *p*-value of <.05 was considered statistically significant. Computations were performed with software R (version 4.1.2), with the packages "Tableone," "Matching," and "RcmdrPlugin. EZR." EZR is an improved version of the R commander, designed to add statistical functions frequently used in biostatistics.[9]

3 | RESULTS

3.1 | Patient enrollment

A total of 908 cases with a PVC burden exceeding 10% were selected from 9046 Holter records. Among these patients, we evaluated 246 (mean age: 65.8 ± 13.8 years, 82 women) with a serial blood test around the time of the Holter ECG. A flowchart of the study selection process is shown in Figure 1. When LVEF was divided by 50%, 162 and 84 patients had normal (≥50%) and impaired (<50%) cardiac systolic functions, respectively. Ninety-one patients (56.2%) in the LVEF ≥50% group and 42 (50.0%) in the LVEF <50% group underwent CA.

3.2 | Patients' characteristics

The baseline characteristics are shown in Table 1. Regardless of the degree of cardiac function, patients who received noninvasive treatment were significantly older than those in the ablation group, and those with vascular events, such as previous myocardial infarction, aortic plaque, or peripheral arterial disease, were less likely to undergo CA. Beta-blockers were prescribed frequently for patients with LVEF <50% (71.2% and 66.7% in the ablation and nonablation groups, respectively), and there was no significant difference in the prescription rates between the two groups. In contrast, patients with an LVEF >50% tended to receive significantly more beta-blockers in the ablation group than in the nonablation group (51.6% vs. 22.5%, $p < .001$).

We adopted propensity score matching to adjust for baseline differences and estimate the effect of CA. The characteristics of

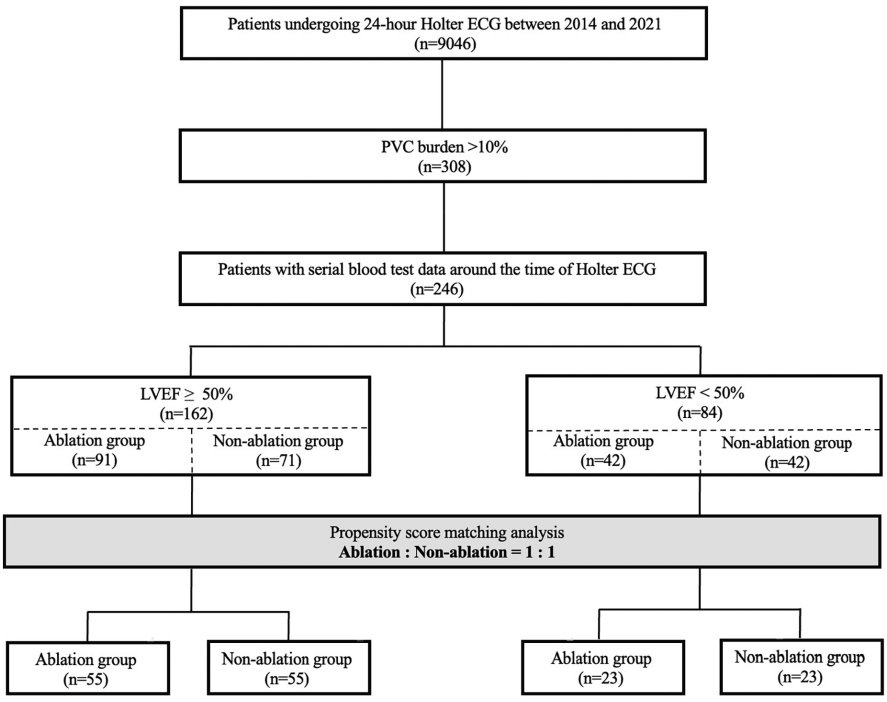

FIGURE 1 Flowchart for patient selection. ECG, electrocardiography; PVC, premature ventricular contraction; LVEF, left ventricular ejection fraction; and CA, catheter ablation.

TABLE 1 Baseline characteristics of the study population.

	LVEF ≥ 50%			LVEF < 50%		
	Catheter ablation (CA) (*n* = 91)	Conservative treatment (*n* = 71)	*p*-value	CA (*n* = 42)	Conservative treatment (*n* = 42)	*p*-value
Age	61.8 ± 16.0	69.2 ± 11.6	.001	63.0 ± 12.7	71.9 ± 9.4	<.001
Male	52 (57.1)	48 (67.6)	.23	29 (69.0)	35 (83.3)	.20
BMI	24.1 ± 3.9	24.6 ± 4.2	.42	23.7 ± 4.2	23.4 ± 4.7	.71
Hypertension	40 (44.0)	36 (50.7)	.49	25 (59.5)	20 (47.6)	.38
Diabetes	17 (18.7)	14 (19.7)	1.00	13 (31.0)	12 (28.6)	1.00
Dyslipidemia	33 (36.3)	29 (40.8)	.67	10 (23.8)	16 (38.1)	.24
Heart failure	12 (13.2)	10 (14.1)	1.00	23 (54.8)	29 (70.7)	.20
Coronary heart disease	7 (7.7)	11 (15.5)	.19	9 (21.4)	16 (38.1)	.15
Dilated cardiomyopathy	6 (6.6)	0 (0.0)	.07	14 (33.3)	8 (19.0)	.22
Hypertrophic Cardiomyopathy	1 (1.1)	2 (2.8)	.83	0 (0.0)	2 (4.8)	.47
Atrial fibrillation	6 (6.6)	10 (14.1)	.19	6 (14.3)	15 (35.7)	.04
Stroke	2 (2.2)	6 (8.5)	.15	3 (7.1)	9 (21.4)	.12
Previous cardiac surgery	3 (3.3)	10 (14.1)	.03	8 (19.0)	5 (11.9)	.55
Vascular disease	1 (1.1)	14 (19.7)	<.001	6 (14.3)	15 (35.7)	.04
CIED	2 (2.2)	7 (9.9)	.08	5 (11.9)	10 (23.8)	.25
Beta blocker	47 (51.6)	16 (22.5)	<.001	30 (71.4)	28 (66.7)	.81
Non-DHP CCB	31 (34.1)	22 (31.4)	.85	11 (26.2)	9 (21.4)	.80
Class1 AAD	9 (9.9)	3 (4.2)	.29	2 (4.8)	1 (2.4)	1.00
Class3 AAD	0 (0.0)	2 (2.8)	.37	4 (9.5)	4 (9.5)	1.00
ACE inhibitor	8 (8.8)	4 (5.6)	.65	13 (31.0)	15 (35.7)	.82
ARB	22 (24.2)	12 (16.9)	.35	12 (28.6)	10 (23.8)	.80
ARNI	1 (1.1)	0 (0.0)	1.00	4 (9.5)	0 (0.0)	.12
Diuretics	13 (14.3)	10 (14.1)	1.00	18 (42.9)	25 (59.5)	.19
Statin	25 (27.5)	22 (31.0)	.75	13 (31.0)	16 (38.1)	.65
Antiplatelet drug	9 (9.9)	15 (21.1)	.08	11 (26.2)	22 (52.4)	.03
Su	2 (2.2)	7 (9.9)	.08	2 (4.8)	6 (14.3)	.27
DOAC	3 (3.3)	4 (5.6)	.74	2 (4.8)	10 (23.8)	.03

Note: Values are presented as the mean ± SD or *n* (%).

Abbreviations: AAD, antiarrhythmic drug; ACE, angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; ARNI, angiotensin receptor neprilysin inhibitor; BMI, body mass index; CA, catheter ablation; CIED, cardiovascular implantable electronic device; DHP CCB, dihydropyridine calcium channel blocker; DOAC, direct oral anticoagulant; LVEF, left ventricular ejection fraction.

the matched patients are shown in Table S1. After propensity score matching, baseline characteristics, including beta-blocker prescription rates, differed insignificantly between the ablation and nonablation groups, regardless of the degree of left ventricular contractility.

3.3 | CA details

The treatment details of CA in all cases are shown in Table 2. The RVOT was the most common origin of PVCs, followed by the aortic cusps and papillary muscles. Similarly, treatment of PVCs of epicardial origin, such as the cardiac crux and LV summit, was included. Other sites of origin included the ventricular septum, tricuspids, and mitral valve annulus. Most ablation energy sources were radiofrequency; however, some cases required cryoablation because of their proximity to the conductive system. Complications associated with ablation included pseudoaneurysm in two cases and cardiac tamponade and wound infection in one case each. The follow-up Holter ECG was performed at the average of 62.6 days after CA. CA reduced the median total number of PVCs in the cohort from 16 139 to 185 beats, and the percentage of PVCs in the total heartbeats decreased from 22.2% to 0.19%. Details of CA after matching are shown in Table S2. In the matched cohort, the median total number of PVCs decreased from 24 711 to 185 beats, and the percentage of PVCs decreased from 24.5% to 0.13%.

TABLE 2 Details of CA.

	All ($n=133$)	LVEF ≥ 50% ($n=90$)	LVEF < 50% ($n=43$)
Origin of PVCs			
RVOT, *n* (%)	37 (25.9)	26 (28.9)	11 (25.6)
LVOT, *n* (%)	35 (24.5)	25 (27.8)	10 (23.3)
PAP, *n* (%)	16 (11.2)	10 (11.1)	6 (14.0)
Epicardial, *n* (%)	12 (8.4)	6 (6.7)	6 (14.0)
Other, *n* (%)	33 (23.1)	23 (25.6)	10 (23.3)
Holter ECG			
Number of PVCs before CA, *n*	16 139 [1591, 32 016]	21 707 [15 993, 30 935]	24 917 [18 911, 36 186]
PVC burden before CA, %	22.2 [15.2, 30.7]	22.0 [14.9, 28.8]	24.0 [16.1, 33.9]
Number of PVCs after CA, *n*	185 [9, 4419]	53 [6, 1979]	1546.0 [143, 7983]
PVC burden after CA, %	0.19 [0.01, 4.5]	0.06 [0.005, 2.0]	1.8 [0.1, 8.1]
Procedural success			
Success, *n* (%)	98 (73.7)	70 (77.8)	28 (65.1)
Partial success, *n* (%)	32 (24.1)	17 (18.9)	15 (34.9)
Failure, *n* (%)	3 (2.2)	3 (3.3)	0 (0)
Complication			
Cardiac tamponade, *n* (%)	2 (1.5)	2 (2.2)	0 (0)
Pseudoaneurysm, *n* (%)	2 (1.5)	1 (1.1)	1 (2.3)
Infection, *n* (%)	1 (0.8)	0 (0)	1 (2.3)
Energy source			
Radiofrequency, *n* (%)	132 (99.2)	89 (98.9)	43 (100.0)
Cryothermy, *n* (%)	5 (3.8)	3 (3.3)	2 (4.7)
Both, *n* (%)	4 (3.0)	2 (2.2)	2 (4.7)
3D mapping system			
CARTO, *n* (%)	111 (83.5)	76 (84.4)	35 (81.4)
EnSite, *n* (%)	22 (16.5)	14 (15.6)	8 (18.6)
Access site			
Transseptal approach, *n* (%)	27 (20.3)	18 (20.0)	9 (20.9)
Transaortic Approach, *n* (%)	49 (36.8)	25 (50.0)	24 (55.8)
Both, *n* (%)	10 (7.5)	8 (8.9)	2 (4.7)
Time			
Procedure time, min	178.5 ± 57.8	173 ± 57.6	187 ± 57.6
Fluro time, min	28.6 ± 18.0	27.1 ± 16.6	31.7 ± 20.5
Radiofrequency time, sec	750.5 ± 700.8	674.7 ± 648.3	894.8 ± 779.0

Note: Values are presented as the mean ± SD or *n* (%).

Abbreviations: CA, catheter ablation; ECG, electrocardiography; LVEF, left ventricular ejection fraction; LVOT, left ventricular outflow tract; PAP, papillary muscle; PVC, premature ventricular contraction; RVOT, right ventricular outflow tract.

3.4 | Change in BNP with and without ablation

In the total cohort, the average interval between the baseline and the follow-up blood test were 57.3 days in the CA group, and 101.3 days in the non-CA group. When BNP values were compared before and after CA for PVC, CA was associated with a significant BNP reduction, irrespective of the baseline LVEF. BNP changed from 44.1 to 33.0 pg/mL ($p=.002$) in the LVEF ≥50% group (Figure 2A) and from 141 to 87.9 ($p<.001$) in the LVEF <50% group (Figure 2B). The BNP levels changed insignificantly in patients allocated to the noninvasive group (Figure 2A,B).

These trends remained unchanged after propensity score matching (Figure S1A,B). The ablation group showed a significant decrease in BNP levels from 52.2 to 38.2 pg/mL before and after the procedure ($p=.004$), while the nonablation group showed a nonsignificant but slight increase from 54.7 to 64.3 pg/mL ($p=.73$).

In the ablation group, patients with abnormally high baseline BNP levels (>100 pg/mL) had a greater reduction in BNP levels

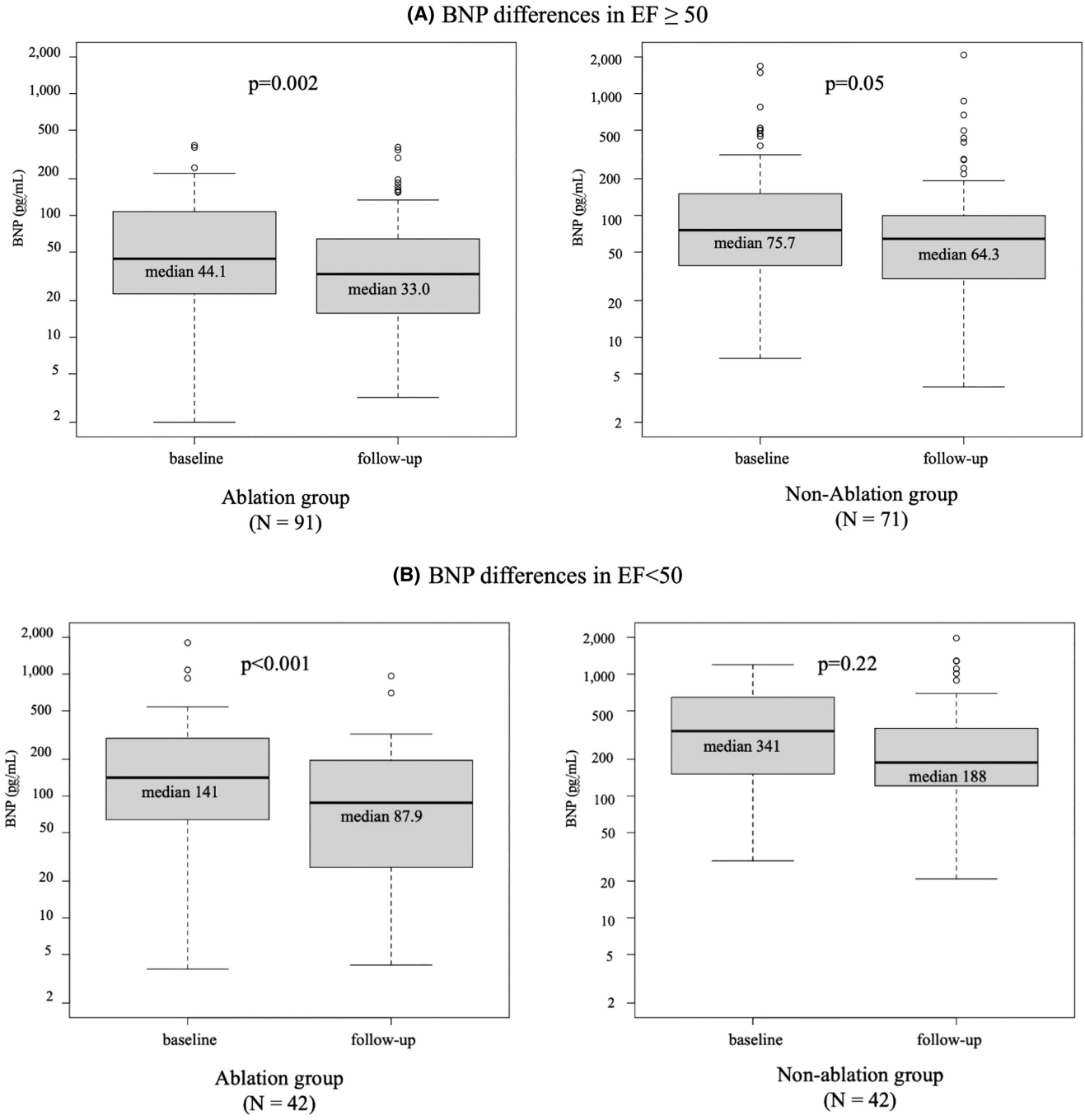

FIGURE 2 Temporal changes in BNP with and without catheter ablation (CA). Changes in BNP levels in patients with LVEF ≥50% are shown in (A), and those in patients with LVEF <50% are shown in (B). Regardless of whether EF was preserved, the BNP levels decreased after treatment in the CA group. In contrast, no significant changes were observed in the non-CA group.

following treatment than those with BNP within the normal range (−5.7 pg/mL in the normal BNP group vs. −81.7 pg/mL in the high BNP group, $p < .01$, Figure S3A).

3.5 | Change in eGFR with and without ablation

In the LVEF ≥50% group, eGFR was significantly increased (from 71.4 to 74.7 mL/min/1.73 m^2, $p = .006$) through the CA procedure, while noninvasive strategy was related to a nonsignificant eGFR decrease (Figure 3A). Similarly, in the group with LVEF less than 50%, eGFR significantly increased from 64.1 to 67.2 in the CA group ($p = .03$), whereas there was a nonsignificant decrease in the non-CA group.(Figure 3B).

These trends remained similar after propensity score matching (Figure S2A,B). In particular, in patients with LVEF >50%, eGFR was significantly increased in the ablation group (from 67.7 to 70.7 mL/min/1.73 m^2, $p = .02$) and was significantly decreased in the nonablation group (from 66.4 to 64.1 mL/min/1.73 m^2, $p = .04$).

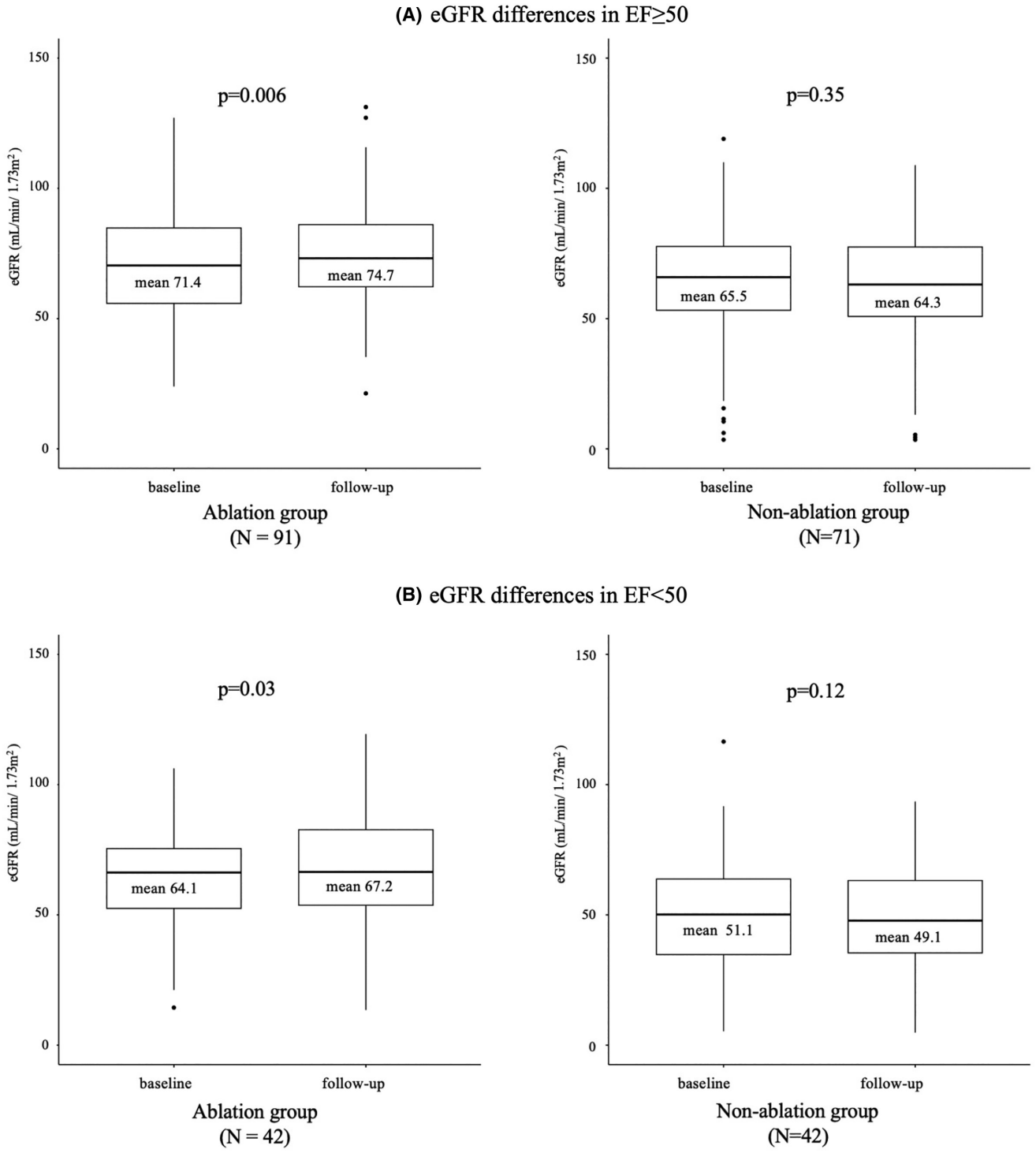

FIGURE 3 Temporal changes in eGFR with and without CA. Changes in eGFR in patients with LVEF ≥50% are shown in (A), and those in patients with LVEF <50% are shown in (B). A significant increase in eGFR was observed in the CA group after treatment, regardless of left ventricular contractility. In the non-CA group, there was a trend toward a decrease in eGFR over time, although the difference was not statistically significant.

Evaluation through preablation renal function showed that the CKD group had a significantly greater increase in postoperative eGFR than the non-CKD group (0.97 mL/min/1.73 m^2 in the non-CKD group vs. 3.8 mL/min/1.73 m^2 in the CKD group, $p = .02$, Figure S3B).

3.6 | Sensitivity analysis excluding AF patients

Since the impact of coexisting AF may have affected the results of this study, a sensitivity analysis was performed after excluding patients with AF. The changes in BNP from 43.6 to 31.7 pg/mL ($p = .003$) in the

CA group and from 66.3 to 59.9 pg/mL ($p=.03$) in the non-CA group for patients with LVEF ≥50%, and from 126 to 74.4 pg/mL ($p<.001$) in the CA group and from 324 to 178 pg/mL ($p=.21$) in the non-CA group for patients with LVEF <50% were observed. The change in eGFR from 72.6 to 75.8 mL/min/1.73 m^2 ($p=.01$) in the CA group and from 67.1 to 66.1 mL/min/1.73 m^2 ($p=.45$) in the non-CA group in patients with LVEF ≥50%, and from 64.3 to 67.5 mL/min/1.73 m^2 ($p=.04$) in the CA group and from 50.4 to 48.9 mL/min/1.73 m^2 ($p=.29$) in the non-CA group in patients with LVEF <50% were observed. The trend of change in BNP and eGFR remained constant regardless of the presence or absence of AF.

3.7 | Correlation between pre-treatment EF and changes in BNP and eGFR after ablation

We assessed pretreatment EF and changes in BNP levels before and after ablation and found that patients with a lower baseline EF had a greater degree of decrease in BNP after treatment (Figure 4A). The changes in eGFR before and after treatment did not correlate with the baseline EF (Figure 4B).

3.8 | Incidence of major cardiovascular events at 1 year after each treatment

Of the total cohort, 18 patients (13.5%) in the CA group and 4 patients (4.4%) in the non-CA group could not complete the 1-year follow-up. The 1-year clinical results for the remaining cohort are presented in Table 3. Major cardiovascular events (all-cause mortality, hospitalization for heart failure, stroke, myocardial infarction, and VT/VF) tended to occur more frequently in the nonablation group than in the ablation group during the 1-year follow-up; however, the change was statistically insignificant. The results were similar regardless of LVEF. Lethal ventricular arrhythmias, such as VT and VF, were not observed in the ablation group; however, they were observed in four patients in the nonablation group. The patients suffering from VT with EF ≥50% had hypertrophic obstructive cardiomyopathy (HOCM) and underwent appropriate ICD therapy, which required subsequent VT ablation. Three patients with EF < 50% and VT, two with dilated cardiomyopathy, and one with old myocardial infarction were treated appropriately with an ICD. The incidence of major cardiovascular events in the matched patients is shown in Table S3.

4 | DISCUSSION

We examined the efficacy of CA compared with noninvasive treatment for frequent PVCs on changes in BNP and eGFR using the propensity score matching. In addition, we evaluated the effect of CA in patients with preserved and impaired cardiac systolic functions. Our data showed that CA may decrease the BNP levels and improve eGFR, regardless of whether cardiac systolic function is preserved. Moreover,

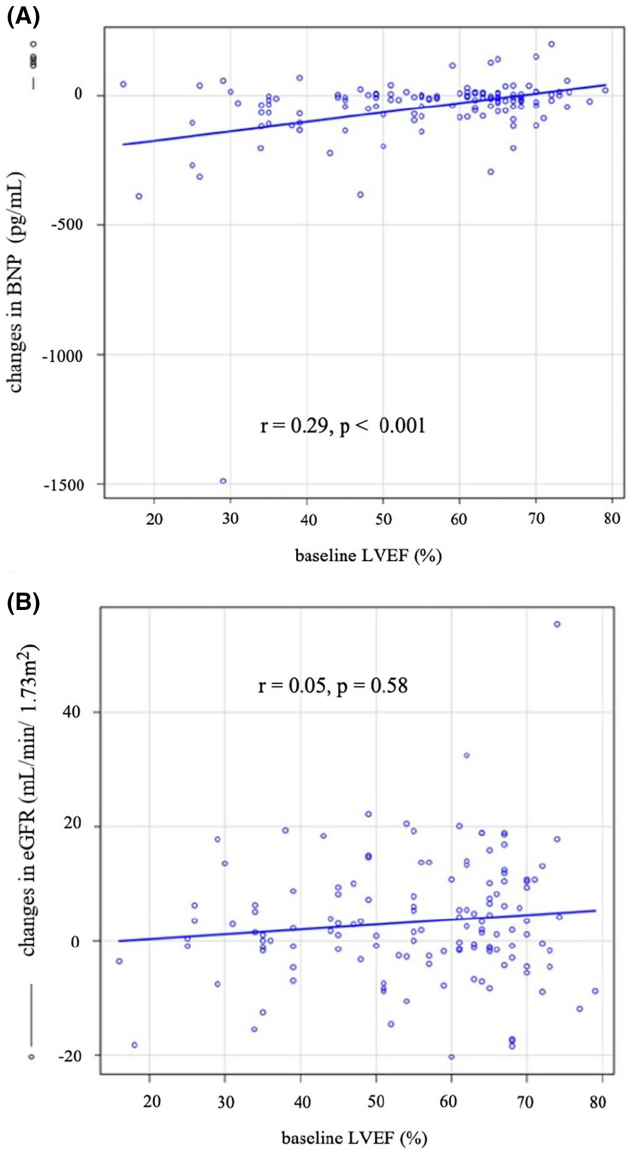

FIGURE 4 Change in BNP and eGFR before and after treatment by the baseline LVEF. The pre-treatment LVEF and the change in BNP before and after ablation are shown in (A), and the change in eGFR is shown in (B). A positive correlation was observed between the baseline EF and the extent of decrease in BNP levels after treatment.

we found a notable improvement in eGFR following CA compared with the gradual worsening of eGFR after noninvasive treatment.

The efficacy of CA for PVCs is well known in patients with impaired cardiac function.[10] however, its effectiveness in idiopathic PVCs with preserved cardiac function remains unclear. CA can restore cardiac function in patients with impaired cardiac function, which may be owing to PIC,[11] or when frequent PVCs in the setting of preexisting structural heart disease further aggravate cardiac function.[12,13] Similarly, in patients with impaired cardiac function, it has been reported that eliminating PVCs with CA can decrease BNP[14] levels and improve eGFR.[8] In contrast, the efficacy of CA in patients with idiopathic PVCs with normal cardiac function has been limited primarily

TABLE 3 Incidence of major cardiovascular events 1 year after each treatment.

	LVEF ≥ 50%			LVEF < 50%		
	CA (*n* = 79)	Non-CA (*n* = 68)	*p*-value	CA (*n* = 35)	Non-CA (*n* = 40)	*p*-value
Death	0 (0)	3 (4.4)	.10	1 (2.9)	3 (7.5)	.62
HF hospitalization	0 (0)	2 (2.9)	.21	3 (8.6)	6 (15)	.49
Stroke	0 (0)	1 (1.5)	.46	0 (0)	1 (2.5)	1.00
MI	2 (2.5)	1 (1.5)	1.00	0 (0)	0 (0)	1.00
VT/VF	0 (0)	1 (1.5)	.46	0 (0)	3 (7.5)	.24

Note: Values are *n* (%).

Abbreviations: CA, catheter ablation; HF, heart failure; MI, myocardial infarction; VT, ventricular tachycardia; VF, ventricular fibrillation.

to the improvement of subjective symptoms such as palpitations[15] and quality of life,[16] and the efficacy and hemodynamic effects in asymptomatic patients have remain unclarified. This study showed that reducing or eliminating PVCs through CA favors hemodynamic parameters, such as improving the eGFR and decreasing the BNP in the impaired (as previously shown) and normal cardiac function groups (as previously shown). The change in eGFR after PVC ablation observed in this study was relatively small with approximately 3 mL/min/1.73 m^2. However, the change was significant and was comparable to previous studies. A study of ablation for PVC-induced cardiomyopathy[8] have reported a change of 6 mL/min/1.73 m^2, and a study of AF ablation[7] have reported a change of 2 mL/min/1.73 m^2. Similarly, the decrease in BNP in this study was relatively small with 11 pg/mL in patients with LVEF >50% and 54 pg/mL in patients with LVEF <50%. The previously reported change after PVC ablation of outflow tract origin was reported to be 23 pg/mL,[14] which was consistent with our study. In addition, the results showed that noninvasive treatment without catheterization gradually decreased eGFR, regardless of whether the LVEF was preserved or reduced. Therefore, even in asymptomatic idiopathic PVCs with normal cardiac function, reduction of PVCs through CA may favor renal and other organ perfusions more than how continuous observational follow-up would.

A mechanism by which renal function improves after CA for PVCs is believed to be the improvement in left ventricular contractility. CA is more effective than antiarrhythmic drugs in eliminating PVCs and improving LVEF as a treatment for frequent PVCs.[17] Therefore, ablation may improve contractility and increase renal blood flow in patients with reduced LVEF owing to frequent PVCs. However, our results showed that BNP and eGFR improved even in patients with preserved LVEF and that improvement in eGFR and baseline EF were not correlated, suggesting that EF improvement is not the only mechanism by which renal function and neurohumoral factors improve and that other mechanisms may contribute to the improvement. Three primary mechanisms were considered to influence the hemodynamic effects of PVCs, even in the absence of left ventricular systolic dysfunction. Stroke volume is reduced regardless of the left ventricular function,[1] which may decrease organ perfusion to the kidneys. Second, venous hypertension may cause organ congestion, as it reportedly increases left ventricular end-diastolic pressure, pulmonary artery wedge pressure, and right atrial pressure.[18] It has been demonstrated that PVC increases systemic sympathetic nerve activity,[19,20] and activating the renin-angiotensin-aldosterone system following sympathetic nerve activity may cause contraction of the anterior glomerular artery and increased reabsorption of sodium and water.[21,22] In conclusion, our results suggest that the cardiorenal syndrome may be triggered by the appearance of arrhythmias, regardless of the degree of left ventricular function.

4.1 | Study limitations

This study had some limitations. This was a single-center retrospective study of consecutive patients who underwent Holter ECGs, and the patient distribution may contain various biases. Although propensity matching was performed, selection bias based on the baseline condition and discretion of the treating physician cannot be eliminated. The changes in PVC burden and LVEF over time were not evaluated routinely, and effect of these factors on changes in eGFR and BNP could not be evaluated. The timing of the follow-up Holter ECG and blood tests were variable due to retrospective nature of this study. The shorter interval of the blood tests in CA group may have affected the results. Treatments other than CA may have affected the changes in eGFR and BNP including pharmacotherapy and lifestyle modifications. There were relatively few PVCs of the right ventricular outflow tract origin in the group that underwent CA, which is considered more frequent and has a higher success rate with CA.[23,24] The present case included PVCs of epicardial and papillary muscle origins, which are relatively challenging to treat.[11] Different results may have been obtained if cases were limited to sites where CA is thought to be more effective. The changes in eGFR and BNP revealed in this study were relatively small, and clinical implications are unknown. The long-term effects of CA on renal and cardiac function, as well as its clinical impact in patients with preserved EF should be elucidated in future prospective studies.

5 | CONCLUSIONS

We compared the effect of CA for frequent PVCs with that of noninvasive treatment using propensity score matching and showed that

CA was related to decreased BNP and increased eGFR. The eGFR worsened in the nonablation group and improved in the ablation group, and the improvement was significant even in patients with preserved left ventricular contractility. This suggests that a close relationship exists between multiple PVCs and renal function and that even patients with preserved left ventricular function may benefit from CA to reduce PVCs.

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CONFLICT OF INTEREST STATEMENT

Authors declare that there no conflicts of interest for this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS APPROVAL STATEMENT

This study was approved by the Ethics committee of Kameda General Hospital.

APPROVAL OF THE RESEARCH PROTOCOL

Data was recorded in a dedicated database in compliance with the ethics committee of our center. The study was conducted according to institutional guidelines and legal requirements and complied with the Declaration of Helsinki.

INFORMED CONSENT

Since this study is a retrospective in nature, informed consent was not required, and an opt-out method was used through the hospital website.

REGISTRY AND THE REGISTRATION NO.

The Institutional Review Board of Kameda General Hospital approved the protocol (approval No. 23-009).

ANIMAL STUDIES

N/A.

PATIENT CONSENT STATEMENT

Since this study is a retrospective in nature, informed consent was not required, and an opt-out method was used through the hospital website.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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