Prognostic value of left ventricular dyssynchrony evaluated by gated myocardial perfusion imaging in patients with chronic kidney disease and normal perfusion defect scores

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Background. **This study aimed to investigate whether indices of left ventricular (LV) dyssynchrony by gated myocardial perfusion SPECT (GMPS) could be useful to predict prognosis in chronic kidney disease (CKD) patients with normal perfusion defect scores.**

Methods. **One hundred and sixty-seven CKD patients with normal perfusion defect scores on adenosine-stress ^{201}Tl GMPS and no previous history of overt heart diseases were enrolled. Phase standard deviation (PSD) and bandwidth (BW) were automatically calculated from GMPS. The major adverse cardiac events (MACEs) for a mean of 560 days were defined as sudden cardiac death, fatal arrhythmias, and acute coronary syndrome requiring urgent coronary revascularization. Patients were divided into two groups according to the presence or absence of MACEs.**

Results. **The MACEs occurred in 12 patients (7.1%). Patients who experienced MACEs showed significantly higher PSD and wider BW than those who did not. In the Kaplan-Meier event-free survival analysis, cardiac event rate was significantly higher in the high-PSD and wide-BW group (n = 81) than in the low-PSD and narrow-BW group (n = 71) (P = .002). The multivariate regression analysis revealed that the PSD was associated with MACEs (odds ratio 1.33, 95% confidence interval 1.05-1.69, P = .01).**

Conclusion. **The LV dyssynchrony indices from GMPS may be novel prognostic predictors in CKD patients with normal perfusion defect scores. (J Nucl Cardiol 2019;26:288–97.)**

Key Words: CKD • gated myocardial SPECT • normal perfusion defect scores • phase analysis • prognosis

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Abbreviations	
BW	Bandwidth
CKD	Chronic kidney disease
EDV	End-diastolic volume
eGFR	Estimated glomerular filtration rate
ESV	End-systolic volume
GMPS	Gated myocardial perfusion SPECT
LVEF	Left ventricular ejection fraction
MACE	Major adverse cardiac event
PSD	Phase standard deviation

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INTRODUCTION

Chronic kidney disease (CKD) is a worldwide public health problem. The number of subjects with CKD can be expected to increase further with the aging of society, resulting in increased medical expense.[1] Since CKD is also known as one of the prognostic predictors of major adverse cardiac events (MACEs),[2,3] early detection of the prevalence of CKD is crucial, and care should be taken for managing CKD patients.

Renal function and myocardial single-photon emission computed tomography (SPECT) have additive value in risk-stratifying patients with suspected coronary artery disease.[4] Large perfusion defect on myocardial SPECT reportedly predicts poor prognosis in CKD patients.[5] On the other hand, some CKD patients without significant perfusion defects and obviously previous heart diseases experience MACEs.[5,6] Since prognostic predictors of MACEs in such CKD patients still remain unclear, it is really important to detect them for such CKD patients.

The left ventricular (LV) dyssynchrony in addition to myocardial perfusion abnormality has recently been assessed simultaneously by electrocardiographically gated myocardial perfusion SPECT (GMPS).[7] Phase standard deviation (PSD) and bandwidth (BW) are new parameters of LV contractile dispersion. It is therefore of interest to examine the prognostic value of these dyssynchrony parameters in CKD patients showing normal perfusion defect scores.

This study aimed to investigate whether or not these parameters could be useful to predict prognosis of CKD patients presenting normal perfusion defect scores.

METHODS

Two hundred and seventy-seven CKD patients who underwent adenosine-stress Tl GMPS between February 2010 and April 2015 were retrospectively analyzed. The following patients were excluded: those with significant defect scores (summed stress defect score ≥ 4)[8] by myocardial SPECT (n = 67), atrial fibrillation (n = 19), and right or left bundle block (n = 24). Finally, 167 patients (118 males, 74 years) were evaluated.

Blood samples were collected from veins to measure biochemical profiles at the entry of the study. The serum creatinine levels were measured using an isotope-dilution mass spectrometry-traceable enzymatic method. The estimated glomerular filtration rate (eGFR) was calculated according to the recently validated equation.[9] CKD was defined as an eGFR <60 mL·min^{-1}·1.73 m^{-2}.

Hypertension was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or the current use of anti-hypertensive agents. Diabetes was defined as fasting plasma levels ≥ 126 mg·dL^{-1}, glycosylated hemoglobin concentration (HbA1c) $\geq 6.5\%$ or the current use of anti-hyperglycemic agents. Dyslipidemia was defined as low-density lipoprotein cholesterol ≥ 140 mg·dL^{-1}, high-density lipoprotein cholesterol <40 mg·dL^{-1}, triglyceride ≥ 150 mg·dL^{-1}, or the current use of lipid-lowering agents.

Twelve-lead surface continuous electrocardiogram was recorded at rest to automatically measure the QRS duration.

The study protocol was approved by the Ethical Committee of Nagoya University Graduate School of Medicine and informed consent was obtained from all patients.

Stress-rest myocardial ^{201}Tl scintigraphy (111 MBq, 3 mCi) was performed at overnight fast, and post-stress images were acquired 10 minutes after tracer injection, whereas rest images were initiated 4 hours after tracer injection. At first, planar images were obtained using a dual-head gamma camera (Symbia T, Siemens, Erlangen, Germany) equipped with a smart zoom collimator. The data were acquired over 6.1° in 17 steps of 30 seconds each on a 128 × 128 matrix. The energy window was 70 keV ± 10%. Acquisition was gated for 8 frames/cardiac cycle. The raw GMPS data were ungated and reconstructed using iterative algorithms. The vertical and horizontal long-axis and short-axis SPECT images were created.

Scintigraphic defect scores were automatically calculated using a 17-segment model with a 5-point scoring system on the polar map images.[8,10] The commercially available software (Heart Function View, Nihon Medi-Physics Co., Ltd., Tokyo, Japan) was applied to calculate LV volumes [end-diastolic volume (EDV) and end-systolic volume (ESV)] and LV ejection fraction (LVEF).[11] The PSD and BW, LV dyssynchrony indices, were automatically calculated using this software. In addition, the time to end-systole, time to peak filling rate, 1/3 filling rate, and peak filling rate were automatically derived by the first derivative of the time-activity curve with a discrete Fourier transform. We used post-stress LV dyssynchrony indices. Normal perfusion defect scores were defined as summed stress score <4.[8,12] The ratio of transient ischemic dilatation was calculated by dividing the computer-derived LV area on the initial image.[13]

All patients were followed up at a mean of 560 days. The MACEs were defined as sudden cardiac death, fatal arrhythmias, and acute coronary syndrome requiring coronary revascularization.

Patients were divided into two groups according to the presence or absence of MACEs.

Table 1. Comparisons of the baseline characteristics between patients who experienced cardiac events and those who did not

Characteristics	All patients	Cardiac events		*P* values
		+	−	
Number of patients	167	12	155	
Age (years)	74 ± 8	73 ± 9	74 ± 8	.92
BMI ($kg{\cdot}m^{-2}$)	23.4 ± 3.4	22.2 ± 1.9	23.5 ± 3.5	.21
BSA (m^2)	1.93 ± 4.00	1.57 ± 0.14	1.96 ± 4.12	.74
Hypertension, n (%)	144 (86)	12 (100)	132 (85)	.15
Diabetes mellitus, n (%)	60 (35)	7 (58)	53 (34)	.08
Dyslipidemia, n (%)	117 (70)	7 (58)	110 (70)	.26
Electrocardiography				
QRS duration (milliseconds)	98 ± 11	107 ± 8	98 ± 11	.007
Laboratory data				
Serum creatinine ($mg{\cdot}dL^{-1}$)	1.90 ± 1.97	2.18 ± 1.73	1.88 ± 1.99	.61
eGFR ($mL{\cdot}min^{-1}{\cdot}1.73\ m^{-2}$)	39.2 ± 15.9	32.8 ± 17.1	39.7 ± 15.7	.14
Hemoglobin ($g{\cdot}dL^{-1}$)	12.1 ± 1.7	12.0 ± 2.2	12.1 ± 1.6	.80
Hematocrit (%)	36.8 ± 4.8	36.5 ± 6.3	36.8 ± 4.7	.81
Albumin ($g{\cdot}dL^{-1}$)	3.9 ± 0.4	3.7 ± 0.4	3.9 ± 0.4	.08
C-reactive protein ($mg{\cdot}dL^{-1}$)	0.40 ± 0.87	0.40 ± 0.61	0.40 ± 0.89	.99
Total cholesterol ($mg{\cdot}dL^{-1}$)	184 ± 38	191 ± 34	183 ± 38	.51
LDL-cholesterol ($mg{\cdot}dL^{-1}$)	103 ± 29	104 ± 23	103 ± 29	.89
HDL-cholesterol ($mg{\cdot}dL^{-1}$)	49 ± 16	54 ± 13	48 ± 16	.35
HbA1c (%)	6.2 ± 0.7	6.3 ± 0.9	6.2 ± 0.7	.69

Values are mean ± 1 SD or number (%)
BMI, body mass index; *BSA*, body surface area; *eGFR*, estimated glomerular filtration rate; *LDL*, low-density lipoprotein; *HDL*, high-density lipoprotein; *HbA1c*, glycosylated hemoglobin concentration

Continuous variables were expressed as mean ± standard deviation and categorical variables as numbers (percentage). Comparisons of continuous variables between the two groups were performed with the unpaired *t* test or the nonparametric Mann-Whitney *U*-test as appropriate. Categorical variables were compared with the χ^2 test or the nonparametric Fisher's exact test as appropriate. The correlation analysis was performed with Pearson's correlation methods. The receiver operating characteristic curve analysis was performed to determine cutoff values of PSD, BW, and EDV for predicting MACEs. Event-free survival was assessed by the Kaplan-Meier analysis. The odds ratios (ORs) and 95% confidence intervals (95% CIs) for each variable were calculated by the univariate logistic regression analysis. Variables showing $P < .10$ on the univariate analysis were entered into the multivariate analysis. The multivariate logistic regression analysis was applied to determine independent predictors for MACEs. The χ^2 analysis was done to examine whether or not an additional prognostic value of phase analysis on LV volume is obtained. An IBM SPSS Statistics 18 software (SPSS, Chicago, IL, USA) was used for the statistical analyses. A *P* value of <.05 was considered statistically significant.

RESULTS

Among 167 patients, 118 patients (70%) were male with a mean age of 74 ± 8 years. One hundred and forty-four patients (89%) had hypertension, 60 patients (35%) had diabetes, and 117 patients (70%) had dyslipidemia. The mean serum creatinine level and eGFR were 1.90 ± 1.97 $mg{\cdot}dL^{-1}$ and 39.2 ± 15.9 $mL{\cdot}min^{-1}{\cdot}1.73\ m^{-2}$, respectively. In electrocardiogram, the mean QRS duration was 98 ± 11 milliseconds.

Twelve patients (7.1% of all patients) experienced MACEs (6 cardiac death, 4 acute coronary syndrome requiring revascularization, and 2 lethal arrhythmias requiring implantable cardioverter defibrillator).

The comparisons of baseline characteristics between patients who experienced MACEs and those who did not are shown in Table 1. The QRS duration was longer in patients who experienced MACEs than those who did not (107 ± 8 vs 98 ± 11 milliseconds, $P = .007$).

Table 2. Characteristics of ^{201}Tl SPECT between patients who experienced cardiac event and those who did not

Variables	All patients (n = 167)	Cardiac events		*P* values
		+ (n = 12)	− (n = 155)	
Stress images				
Heart rate (bpm)	65.7 ± 12	62.7 ± 13	65.9 ± 11	.37
Summed stress score	1.0 ± 0.9	1.0 ± 0.8	1.0 ± 1.0	.88
EDV (mL)	57.2 ± 19.9	72.4 ± 29.8	56.1 ± 18.6	.006
ESV (mL)	26.0 ± 12.1	35.0 ± 16.2	25.4 ± 11.5	.008
EF (%)	55.5 ± 8.0	52.0 ± 4.8	55.8 ± 8.2	.11
Time to end-systole (milliseconds)	383 ± 41	406 ± 42	382 ± 41	.04
Time to peak filling rate (milliseconds/R-R)	0.29 ± 0.03	0.28 ± 0.04	0.29 ± 0.02	.40
1/3 Filling rate (mL·s^{-1})	1.5 ± 0.4	1.3 ± 0.3	1.5 ± 0.4	.07
Peak filling rate (mL·s^{-1})	2.1 ± 0.6	1.8 ± 0.4	2.2 ± 0.6	.07
PSD (°)	3.8 ± 1.9	5.4 ± 2.3	3.7 ± 1.8	.02
BW (°)	13.6 ± 6.9	19.5 ± 9.0	13.2 ± 6.6	.03
TID ratio	1.08 ± 0.11	1.08 ± 0.13	1.08 ± 0.11	.84

Values are mean ± 1 SD or number (%)
^{201}Tl, thallium-201; *SPECT*, single-photon emission computed tomography; *PSD*, phase standard deviation; *BW*, bandwidth; *EDV*, end-diastolic volume; *ESV*, end-systolic volume; *EF*, ejection fraction; *TID*, transient ischemic dilatation

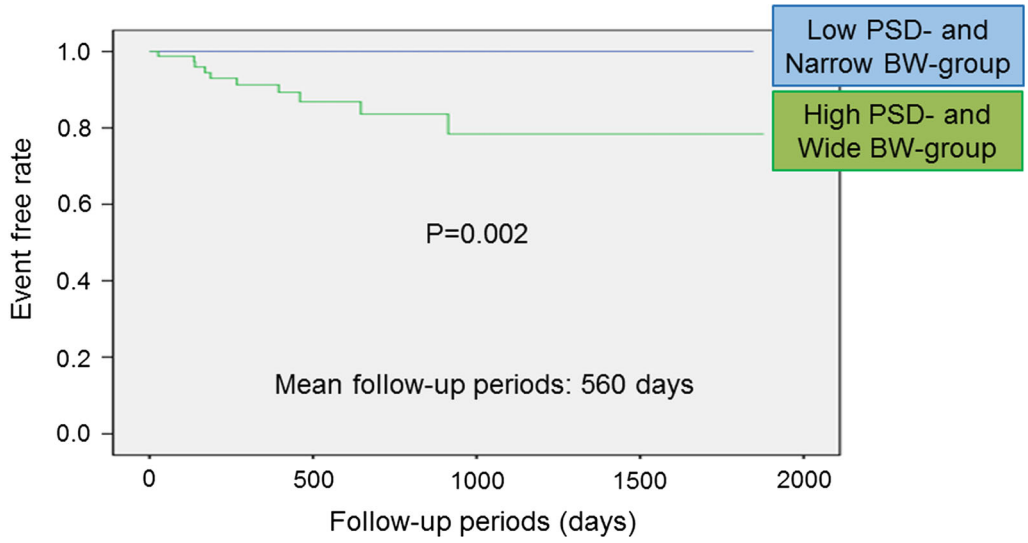
The comparisons of ^{201}Tl SPECT findings between both groups are shown in Table 2. The mean stress LVEF was 55.5 ± 8.0%. The total sum of defect score on the stress image was 1.0 ± 0.9. The stress PSD and BW were 3.8 ± 1.9° and 13.6 ± 6.9°, respectively.

The stress EDV was significantly greater in patients who experienced MACEs than those who did not (72.4 ± 29.8 vs 56.1 ± 18.6 mL, $P = .006$). The stress ESV was significantly greater in patients who experienced MACEs than those who did not (35.0 ± 16.2 vs

Table 3. Binary logistic regression analysis for the cardiac event

Variables	Univariate			Multivariate		
	Odds ratio	95% CI	*P* values	Odds ratio	95% CI	*P* values
Age	0.99	0.92–1.06	.92			
BMI	0.88	0.72–1.07	.20			
eGFR	0.97	0.94–1.00	.15			
Hemoglobin	0.95	0.68–1.34	.80			
C-reactive protein	0.99	0.43–2.30	.99			
LDL-cholesterol	1.00	0.98–1.02	.88			
HbA1c	1.22	0.45–3.26	.68			
SSS	0.95	0.52–1.73	.87			
EDV	1.03	1.00–1.05	.01	1.02	1.00–1.05	.03
EF	0.93	0.86–1.01	.11			
TID ratio	1.63	0.12–224.54	.84			
PSD	1.35	1.08–1.69	.007	1.33	1.05–1.69	.01

Variables with a *P* value ≤.01 were included in the multivariate analysis. EDV, EF, and PSD are calculated in the stress phase
CI, confidence interval; *BMI*, body mass index; *eGFR*, estimated glomerular filtration rate; *LDL*, low-density lipoprotein; *HbA1c*, glycosylated hemoglobin concentration; *SSS*, summed stress score; *EDV*, end-diastolic volume; *EF*, ejection fraction; *TID*, transient ischemic dilatation; *PSD*, phase standard deviation



	Low PSD- and Narrow BW-group n = 71	High PSD- and Wide BW-group n = 81
Composite of cardiac events	**0**	**10**
Cardiac death	0	5
Unstable angina with revascularization	0	4
Lethal Arrhythmias	0	1

Figure 1. Kaplan-Meier event-free survival analysis. Ten of 152 patients experienced cardiac events. In the Kaplan-Meier event-free survival analysis, cardiac event rate was significantly higher in the high-phase standard deviation (PSD) and wide-bandwidth (BW) group than in the low-PSD and narrow-BW group ($P = .002$).

25.4 ± 11.4 mL, $P = .008$). The stress time to end-systole was significantly longer in patients who experienced MACEs than those who did not (406 ± 42 vs 382 ± 41 milliseconds, $P = .04$). The stress PSD was significantly higher and stress BW was significantly wider in patients who experienced MACEs than those who did not (PSD 5.4 ± 2.3 vs 3.7 ± 1.8°, $P = .02$; BW 19.5 ± 9.0 vs 13.2 ± 1.6°, $P = .03$, respectively). No significant difference in the ratio of transient ischemic dilatation was observed between the two groups.

In the univariate logistic regression analysis, PSD and EDV on the stress images were associated with MACEs, but the ratio of transient ischemic dilatation was not associated with MACEs. The multivariate logistic regression analysis displayed that PSD and EDV were significant and independent predictors for MACEs (PSD, OR 1.33, 95% CI 1.05-1.69, $P = .01$; EDV, OR 1.02, 95% CI 1.00-1.05, $P = .03$, respectively, Table 3).

There is a significant correlation between PSD and BW ($r = .981$, $P < .0001$). The cutoff value of PSD and BW for predicting MACEs were 3.3 and 12.5, respectively. The cutoff value of EDV for predicting MACEs was 59.9 mL. Among the 167 patients, 81 patients showed high-PSD (PSD ≥3.3) and wide-BW (BW ≥12.5), whereas 71 patients showed low-PSD (PSD <3.3) and narrow-BW (BW <12.5). Seventy-one patients showed large EDV (EDV ≥59.9 mL), whereas 96 patients showed small EDV (EDV <59.9 mL). In the Kaplan-Meier event-free survival analysis, cardiac event rate was significantly higher in the high-PSD and wide-BW group than in the low-PSD and narrow-BW group ($P = .002$, Figure 1). One hundred and twenty, 26, and 21 patients were classified in CKD stage 3, stage 4, and stage 5, respectively. The MACEs were observed in 6, 4, and 2 patients, respectively. Cardiac event rates in the Kaplan-Meier event-free survival analysis were similar ($P = .28$).

In the χ^2 analysis, event rate was significantly higher in the large-EDV, high-PSD, and wide-BW group than in the small-EDV, low-PSD, and narrow-BW group. However, the incremental prognostic value was not obtained after combined analysis (Table 4).

The representative two cases of phase analysis and SPECT images are presented in Figure 2A-D.

Table 4. χ^2 tests between patients with and without cardiac events

Variables	n	Cardiac events		*P* values
		+	−	
Small-EDV group	96	2	94	.003
Large-EDV group	71	10	61	
Low-PSD and narrow-BW group	71	0	71	.001
High-PSD and wide-BW group	81	10	71	
Small-EDV, low-PSD, and narrow-BW group	47	0	47	.001
Large-EDV, high-PSD, and wide-BW group	45	9	36	

EDV, end-diastolic volume; *ESV*, end-systolic volume; *PSD*, phase standard deviation; *BW*, bandwidth

DISCUSSION

The prevalence of intramyocardial circulatory dysfunction may be an important factor which induces future MACEs in CKD patients. The LV hypertrophy often observed in CKD patients yields intramyocardial circulatory dysfunction. In addition, intramyocardial arteriolar wall thickening in the myocardium has reportedly been identified in experimental uremia.[14] Diminished LV capillary supply in renal failure may increase critical oxygen diffusion disorder in the myocardium, exposing cardiomyocytes to hypoxia. Interstitial fibrosis in the myocardium is reportedly more severe particularly in patients with end-stage renal disease than those with primary hypertension and diabetes mellitus.[15] These myocardial abnormalities in CKD patients cause microcirculatory disturbances and render the myocardium more susceptible to hypoxic injury. Accordingly, the prevalence of coronary artery stenosis or spasm is thought to exacerbate myocardial ischemia more in patients with end-stage renal disease.[16] In addition, such hypoxic status may cause fatal arrhythmias in CKD patients regardless of the presence of significant epicardial coronary stenosis.

Endothelial dysfunction in the epicardial coronary artery is observed in CKD patients without significant coronary stenosis and may play an important role in myocardial microcirculatory disturbance via microcirculatory endothelial dysfunction or spasm.[17,18] Endothelial dysfunction of the epicardial coronary artery eventually leads to myocardial dysfunction.

Recently, Nishimura et al investigated prognostic values of cardiac death in hemodialysis patients without obstructive coronary artery disease.[19] They reported that impaired myocardial fatty acid metabolism is a strong predictor for cardiac death. Moreover, they speculated that the presence of epicardial coronary endothelial dysfunction and/or microcirculatory disturbance in the myocardium plays key roles in myocardial metabolic abnormality.

Other possible mechanisms of developing myocardial damage in CKD patients are considered to involve the prevalence of uremic toxins. Uremic toxins induce epicardial coronary endothelial dysfunction.[20] Indoxyl sulfate is a potent uremic toxin with both cardiovascular and uremic toxicity. A decline in eGFR was significantly associated with an increase in the plasma indoxyl sulfate, and the plasma indoxyl sulfate level was a significant predictor of MACEs, especially in patients with CKD.[21] The association between elevated plasma indoxyl sulfate and increased risk of LV diastolic dysfunction has been also reported.[22] Since we did not examine the effects of uremic toxins on LV dyssynchrony in this study, this issue warrants further investigations. As mentioned above, intramyocardial circulation abnormalities due to myocardial hypertrophy or structural changes in intramyocardial vasculature, metabolic disorder, epicardial coronary endothelial dysfunction, and the presence of uremic toxins in CKD patients may lead to LV dyssynchrony regardless of the presence of significant coronary stenosis.

One may think that we misclassified some CKD patients with multi-vessel disease when the perfusion defect analysis was conducted, because it is well known that conventional perfusion SPECT often underestimate such patients due to globally balanced ischemia.[13] Indeed, one representative case died of acute myocardial infarction. However, acute coronary syndrome often occurs even in patients without significant coronary stenosis (luminal stenosis <50%). In addition, none of the patients showed transient ischemic dilatation on post-stress images,[13] which is a validated phenomenon indicating global endomyocardial ischemia involved in the presence of multi-vessel disease. Therefore, we consider that our patients did not have physiologically significant coronary stenosis at baseline.

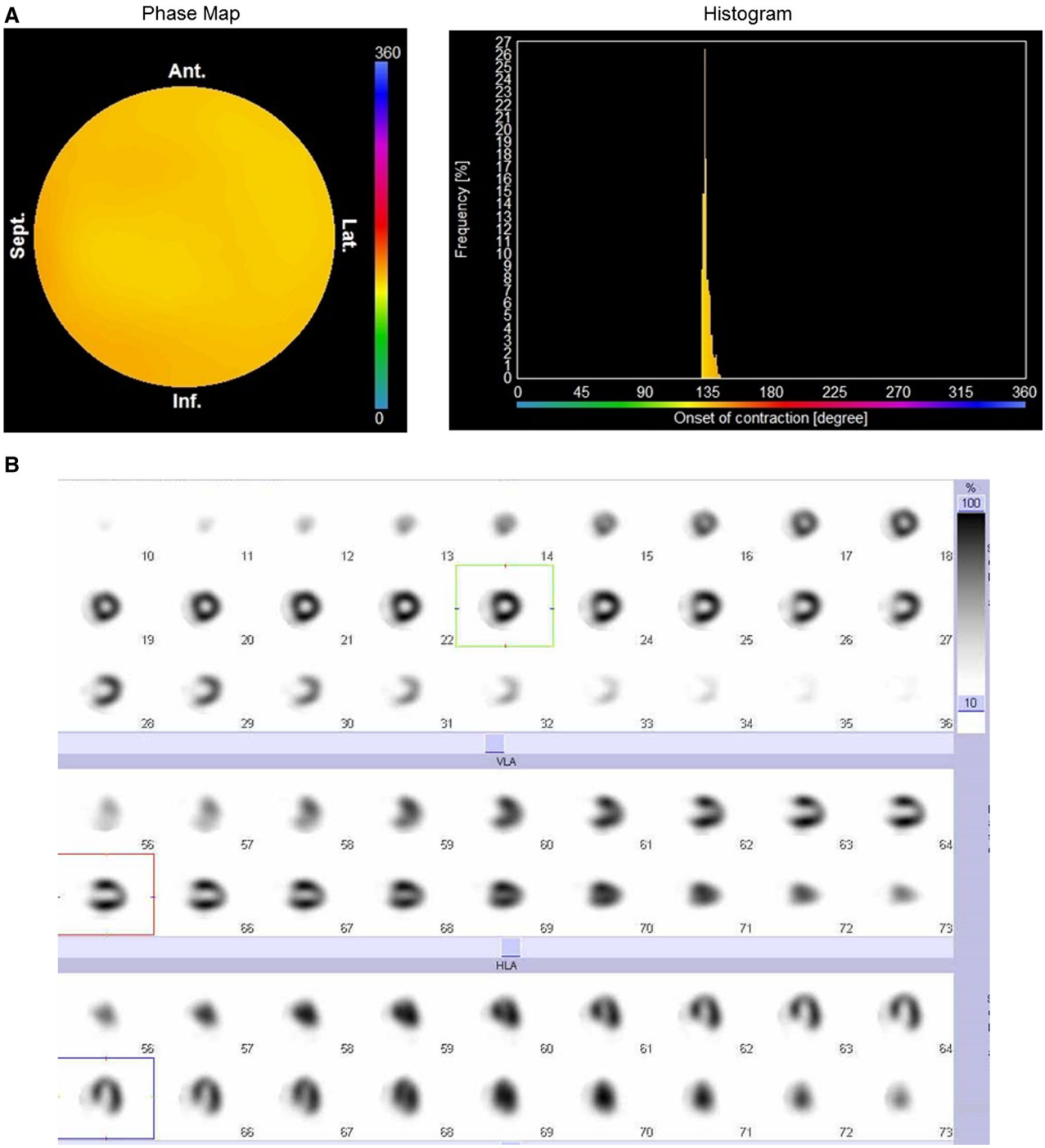


Figure 2. Representative cases of each group. (**A**) Myocardial ^{201}Tl SPECT, phase map, and histogram of a 71-year-old female. The phase standard deviation (PSD) and bandwidth (BW) are 1.95 and 7, respectively. In this case, there was no cardiac event in the follow-up period. (**B**) SPECT images of this patient. SSS was 0. (**C**) Myocardial ^{201}Tl SPECT, phase map, and histogram of a 73-year-old female. The PSD and BW are 3.25 and 31, respectively. In this case, the patient died of acute myocardial infarction 136 days after myocardial ^{201}Tl SPECT. (**D**) SPECT images of this patient who experienced MACE. SSS was 2.

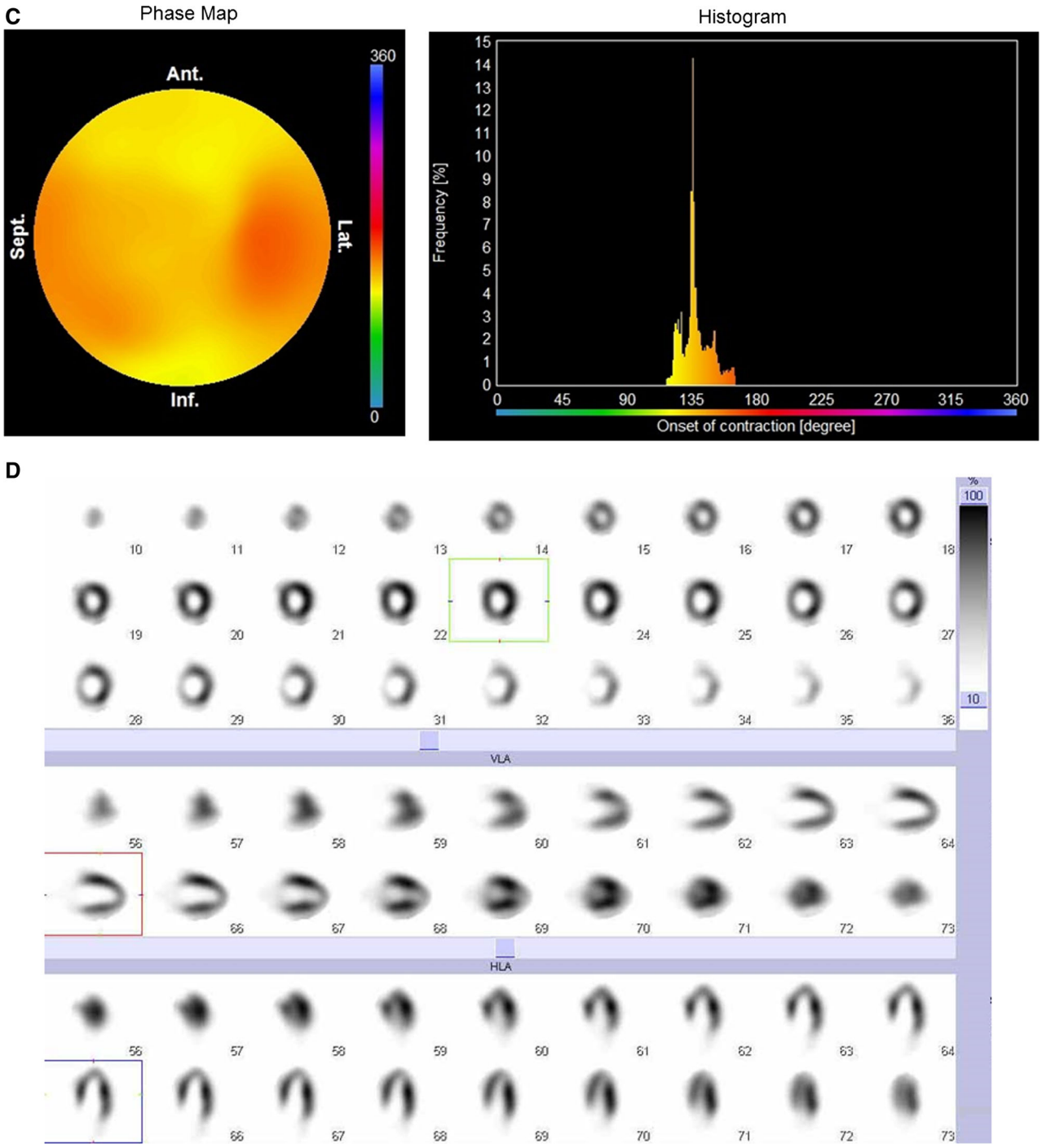


Figure 2. continued.

A recent study indicated that an additive LV dyssynchrony analysis to conventional perfusion analysis is useful to detect patients with multi-vessel disease.[23] Another study demonstrated that LV dyssynchrony is an independent predictor of death in patients with coronary artery disease and reduced LV systolic function.[24] LV dyssynchrony analysis may be useful to detect even CKD patients with multi-vessel disease. It is not surprising that CKD patients showing a large defect on SPECT exhibit poor prognosis. However, some CKD

patients without significant scintigraphic ischemia experience MACEs. In addition, MACEs were reported in CKD patients without significant coronary artery stenosis.[25] Therefore, it is of interest to detect prognostic predictors for such CKD patients.

A previous study demonstrated that BW is a predictor for MACE in end-stage renal disease.[26] Although we investigated the prognostic value of LV dyssynchrony indices in only CKD patients with normal perfusion defect, our results were in accord with the previous study. We evaluated LV dyssynchrony with phase analysis derived from GMPS. The septal-to-posterior wall motion delay is another dyssynchrony index by echocardiography. However, echocardiography is examiner-dependent and poor penetration hinders precise evaluation of dyssynchrony. Our software algorithm applied in this study is automatically processed with higher reproducibility and more excellent repeatability than the examiner-dependent echocardiographic evaluations. The septal-to-posterior wall motion delay on echocardiography indicates the time difference of a peak displacement between septal and posterior wall in a certain cross-section of the LV, whereas LV dyssynchrony assessed by the phase analysis using GMPS reflects global and detailed dyssynchrony of LV mechanical contraction than septal-to-posterior wall motion delay using echocardiography.[27] Accordingly, PSD and BW could reflect more global and detailed LV dyssynchrony than the echocardiographic parameters. PSD and BW may be parameters to reflect the prevalence of myocardial damage independent of myocardial ischemia due to significant epicardial coronary stenosis.

In our study, ^{201}Tl-radiolabeled tracers were used for measuring PSD and BW. Actually, the use of ^{99m}Tc-radiolabeled tracers is considered to be standard. However, Chen et al showed that a good correlation of dyssynchrony indices is observed between ^{201}Tl and ^{99m}Tc.[28] In addition, we did not compare our data with validated ^{201}Tl-based normal data. We investigated only Japanese CKD patients who have smaller physique compared with Western people so that ^{201}Tl is well feasible for the application of the phase analysis with an excellent image quality as well as ^{99m}Tc-based tracers. A recent study demonstrated that LV dyssynchrony parameters significantly differ among software programs.[29] An additional prognostic value of phase analysis over EDV was not obtained. Accordingly, these issues warrant further investigations with larger population, and our data may not be extrapolated. Significant differences in PSD and BW were observed between patients who experienced MACEs and those who did not. However, we included only PSD into multivariate analysis because there was a collinearity between PSD and BW ($r = .981$). A diastolic dyssynchrony index may be valuable to be assessed for CKD patients with suspected coronary artery disease.[30] Since the current software does not dedicate an application to calculate it, we could not assess it.

CONCLUSIONS

The LV dyssynchrony indices noninvasively calculated by GMPS may be novel prognostic predictors in CKD patients presenting normal perfusion defect scores on myocardial SPECT. However, this is a single center and retrospective study with a limited number of CKD patients. A Larger prospective study will be needed to confirm the prognostic implications.

NEW KNOWLEDGE GAINED

The PSD and BW, indices reflecting global LV mechanical contraction, were greater in CKD patients with normal perfusion defect on SPECT who experienced MACEs. The multivariate analysis revealed a significant association of MACEs with PSD and BW. Kaplan-Meier event-free survival analysis revealed a higher event rate in CKD patients showing high-PSD and wide-BW group than in those showing low-PSD and narrow-BW group.

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Disclosure

The authors declare that they have no conflict of interest and financial disclosures.

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