Supplementary Table 1. Comparison of clinical and electrocardiographic characteristics of patients with and without late potentials on SAECG

Characteristic	Number of patients (N = 358)	No late potentials (N=270)	Yes late potentials (N=88)
Demographic and Clinical Characteristics			
Mean age (SD), years	**358**	**53 (13)**	**60 (14)**
Men, n (%)	**358**	**151 (56)**	**61 (69)**
African American, n (%)	**358**	**210 (78)**	**52 (59)**
Mean BMI (SD), kg/m^2	357	29.5 (7.8)	29.3 (8.1)
Diabetes, n (%)	358	155 (57)	52 (59)
Hypertension, n (%)	358	270 (100)	88 (100)
Coronary artery disease, n (%)	358	92 (34)	40 (45.5)
Ever smoker, n (%)	358	159 (59)	61 (69)
Beta-blocker, n(%)	322	167 (69)	59 (73)
ACE inhibitor, n (%)	322	81 (34)	29 (36)
Angiotensin-receptor blocker, n (%)	322	25 (10)	8 (10)
Calcium channel blocker, n(%)	322	147 (61)	49 (60)
3-month averaged calcium (SD), mg/dL	355	8.6 (0.6)	8.7 (0.6)
3-month averaged potassium (SD), mEq/L	355	4.4 (0.5)	4.3 (0.4)
3-month averaged magnesium (SD), mg/dL	334	2.2 (6.1)	1.7 (0.3)
Dialysate calcium (%), mEq/L*	349		
2		117 (45)	28 (32)
2.25		12 (5)	3 (3)
2.5		131 (50)	56 (64)
3		2 (1)	0
Dialysate potassium (%), mEq/L*	350		
1		2 (1)	2 (2)
2		222 (84)	72 (83)
3		39 (15)	13 (15)
3-month averaged intradialytic weight change (SD), kg	349	2.3 (0.9)	2.3 (0.8)
Left ventricular function			
Mean left ventricular ejection fraction (SD)	351	65.9 (12.3)	64.5 (11.1)
Mean left ventricular mass index (SD),g/m$^{2.7}$	350	66.5 (23.1)	66.8 (19.8)
12-lead ECG characteristics			
Mean heart rate (SD), bpm	306	71.7 (11.4)	70.7 (10.2)
Median heart rate variance (IQR), ms	306	363 (122, 1086)	341 (137, 1093)
Mean QRS duration (SD), ms	**358**	**95.5 (13.8)**	**115.5 (22.9)**
Complete bundle branch block, n (%)	**358**	**8 (3)**	**20 (23)**
Mean spatial QRS-T angle (SD)	358	89.7 (46.7)	92.4 (42.4)

Supplementary Table 2. Comparison of baseline clinical and electrocardiographic characteristics of hemodialysis participants with and without outcome

Characteristics	All-cause mortality	
	Yes (N = 77)	No (N = 281)
Demographic and clinical characteristics		
Mean age (SD), years	59 (13)	54 (13)
Men, n (%)	43 (56)	169 (60)
African American, n (%)	52 (68)	210 (75)
Mean BMI (SD), kg/m^2	27.8 (7.9)	29.9 (8)
Diabetes, n (%)	49 (64)	158 (56)
Hypertension, n (%)	77 (100)	281 (100)
Coronary artery disease, n (%)	34 (44)	98 (35)
Family history of CHD, n (%)	31 (40)	122 (43)
Family history of sudden death, n (%)	9 (12)	26 (9)
Ever smoke, n (%)	51 (66)	169 (60)
Ever alcohol use, n (%)	58 (77)	229 (82)
Beta-blocker, n (%)	42 (64)	184 (72)
ACE inhibitor, n (%)	32 (49)	78 (31)
Angiotensin-receptor blocker, n (%)	6 (9)	27 (11)
Calcium channel blocker, n(%)	29 (44)	167 (65)
3-month averaged calcium (SD), mg/dL	8.5 (0.7)	8.7 (0.6)
3-month averaged potassium (SD), mEq/L	4.3 (0.6)	4.4 (0.5)
3-month averaged magnesium (SD) , mg/dL	1.7 (0.2)	2.1 (6.0)
3-month averaged albumin (SD), g/dL	3.4 (0.5)	3.7 (0.4)
3-month averaged creatinine (SD), mg/dL	6.2 (2.1)	7.3 (2.6)
Mean non-dialysis seated systolic BP (SD), mmHg	137.3 (20.8)	137.3 (25.6)
Mean non-dialysis seated diastolic BP (SD), mmHg	73.7 (13.7)	75.1 (15.1)
Dialysate calcium (%), mEq/L		
2	30 (40)	115 (42)
2.25	5 (6)	10 (3)
2.5	40 (53)	147 (54)
3	1 (1)	1 (1)
Dialysate potassium (%), mEq/L		
1	0 (0)	4 (2)
2	60 (79)	234 (85)
3	16 (21)	36 (13)

Left ventricular function by echocardiogram		
Mean left ventricular ejection fraction (SD)	62.9 (12.4)	66.2 (11.9)
Mean left ventricular mass index (SD), $g/m^{2.7}$	67.8 (20.9)	66.3 (22.7)
LVH, n(%)	57 (77)	205 (74)
Mean left ventricular end diastolic diameter (SD), cm	5.4 (0.7)	5.3 (0.7)
Mean left ventricular end systolic diameter (SD), cm	3.3 (0.9)	3.2 (0.8)
12-lead ECG characteristics		
Mean heart rate (SD), bpm	71.2 (10.8)	71.5 (10.8)
Median heart rate variability (IQR), ms	376 (114, 1076)	356 (127, 1098)
Mean QTc (SD), ms	483.2 (39.5)	484.9 (44.7)
Mean QRS duration (SD), ms	98.4 (17.3)	101.0 (18.9)
Complete bundle branch block, n (%)	6 (8)	22 (8)
Mean spatial QRS-T angle (SD)	99.7 (41.3)	87.8 (46.5)
Signal averaged ECG (SAECG) characteristics		
Median filtered QRS duration (IQR), ms	112 (106, 122)	113 (106, 124)
Median LAS40 (IQR)	28 (20, 36)	29 (20, 37)
Median RMS40 (IQR)	46 (26, 59)	36 (23, 56)
Median noise (IQR), µV	0.3 (0.2, 0.4)	0.3 (0.2, 0.4)
Late potentials on SAECG, n (%)	19 (25)	69 (25)

SD=standard deviation. BMI=Body mass index. CVD=cardiovascular disease. CHD=coronary heart disease. LVH=left ventricular hypertrophy. LAS40=duration of the low-amplitude signals (<40 mV) in the terminal QRS portion. RMS40=root-mean-square voltage of the last 40

Supplementary Table 3. Sensitivity analysis examining the association of spatial QRS-T angle with all-cause mortality, cardiovascular mortality, and sudden cardiac death within 1 year using Cox proportional hazards model

Model	Per 10° of spatial QRS-T angle		Spatial QRS-T angle ≥ 75°	
	HR (95% CI)	P	HR (95% CI)	P
All-cause mortality[†]				
Unadjusted	1.08 (1.00, 1.17)	0.06	1.95 (0.86, 4.44)	0.11
Model 1*	1.08 (1.00, 1.18)	0.05	2.08 (0.91, 4.77)	0.08
Model 2**	1.09 (1.00, 1.19)	0.04	2.21 (0.93, 5.23)	0.07
Cardiovascular mortality[†]				
Unadjusted	1.12 (0.99, 1.26)	0.07	2.82 (0.78, 10.15)	0.11
Model 1*	1.12 (0.99, 1.26)	0.07	2.94 (0.81, 10.69)	0.10
Model 2**	1.13 (0.99, 1.28)	0.06	3.07 (0.80, 11.74)	0.10
Sudden cardiac death[†]				
Unadjusted	1.13 (0.96, 1.32)	0.14	2.47 (0.50, 12.25)	0.27
Model 1*	1.12 (0.95, 1.30)	0.17	2.51 (0.50, 12.69)	0.27
Model 2**	1.15 (0.97, 1.36)	0.12	3.00 (0.53, 17.09)	0.22

[†] There were 29 deaths, of which, 14 were due to cardiovascular causes. Of the 14 deaths, 8 were sudden cardiac deaths.

* Model 1 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race
** Model 2 includes variables in Model 1, beta-blocker medication, coronary artery disease, LVMI

Supplementary Table 4. Association of late potential on signal averaged electrocardiogram (SAECG) with all-cause mortality, cardiovascular mortality, and sudden cardiac death among incident hemodialysis

Model	Late potential on SAECG	
	HR (95% CI)	P
All-cause mortality		
Unadjusted	1.15 (0.66, 2.00)	0.63
Model 1*	0.99 (0.56, 1.75)	0.98
Model 2**	0.99 (0.56, 1.75)	0.98
Cardiovascular mortality		
Unadjusted	0.70 (0.28, 1.76)	0.45
Model 1*	0.66 (0.26, 1.72)	0.40
Model 2**	0.67 (0.26, 1.73)	0.41
Sudden cardiac death		
Unadjusted	1.03 (0.29, 3.67)	0.96
Model 1*	0.96 (0.26, 3.52)	0.96
Model 2**	1.12 (0.30, 4.23)	0.86

* Model 1 includes the main exposure (Late potential on SAECG), age, sex, race

** Model 2 includes variables in Model 1, beta-blocker medication, coronary artery disease, LVMI

Supplementary Table 5. Sensitivity analysis examining the association of spatial QRS-T angle with all-cause mortality, cardiovascular mortality, and sudden cardiac death using Cox proportional hazards model in patients without total bundle branch block

Model	Per 10° of spatial QRS-T angle			Spatial QRS-T angle ≥ 75°		
	HR (95% CI)	P	P interaction**	HR (95% CI)	P	P interaction**
All-cause mortality						
Unadjusted	1.06 (1.01, 1.12)	0.03	0.26	2.36 (1.39, 3.99)	0.001	0.08
Model 1*	1.06 (1.01, 1.12)	0.03		2.68 (1.54, 4.66)	< 0.001	
Cardiovascular mortality						
Unadjusted	1.09 (1.01, 1.18)	0.03	0.11	3.16 (1.37, 7.29)	0.01	0.09
Model 1*	1.10 (1.02, 1.19)	0.02		3.68 (1.53, 8.80)	0.003	
Sudden cardiac death						
Unadjusted	1.08 (0.97, 1.21)	0.18	0.99	3.42 (0.97, 12.14)	0.06	0.99
Model 1*	1.11 (0.98, 1.25)	0.11		4.52 (1.17, 17.40)	0.03	

* Model 1 includes the main exposure, age, sex, race, beta-blocker medication, coronary artery disease, LVMI

** Statistical interaction between the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle) and total bundle branch block in model 1 that included the main exposure, age, sex, race, beta-blocker medication, coronary artery disease, LVMI, and total bundle branch block

Supplementary Table 6. Sensitivity analysis examining the association of spatial QRS-T angle with all-cause mortality, cardiovascular mortality, and sudden cardiac death using Cox proportional hazards model excluding patients with QRS duration ≥120 ms

Model	Per 10° of spatial QRS-T angle		Spatial QRS-T angle ≥ 75°	
	HR (95% CI)	P	HR (95% CI)	P
All-cause mortality				
Unadjusted	1.08 (1.02, 1.14)	0.004	2.73 (1.60, 4.67)	< 0.001
Model 1*	1.09 (1.03, 1.15)	0.003	3.15 (1.80, 5.53)	< 0.001
Cardiovascular mortality				
Unadjusted	1.10 (1.02, 1.19)	0.01	3.45 (1.50, 7.95)	0.004
Model 1*	1.12 (1.03, 1.21)	0.01	4.07 (1.70, 9.75)	0.002
Sudden cardiac death				
Unadjusted	1.09 (0.98, 1.22)	0.12	3.73 (1.05, 13.23)	0.04
Model 1*	1.12 (0.99, 1.26)	0.07	4.78 (1.24, 18.38)	0.02

* Model 1 includes the main exposure, age, sex, race, beta-blocker medication, coronary artery disease, LVMI

Supplementary Table 7. Sensitivity analysis examining the association of spatial QRS-T angle with all-cause mortality, cardiovascular mortality, sudden cardiac death, after additionally adjustment for serum and dialysate electrolytes, intradialytic weight change, or albumin

Model	Per 10° of spatial QRS-T angle		Spatial QRS-T angle ≥ 75°	
	HR (95% CI)	P	HR (95% CI)	P
All-cause mortality				
Model 1[1]	1.05 (1.00, 1.11)	0.06	2.30 (1.36, 3.90)	0.002
Model 2[2]	1.06 (1.00, 1.11)	0.04	2.39 (1.41, 4.07)	0.001
Model 3[3]	1.06 (1.00, 1.11)	0.04	2.41 (1.41, 4.14)	0.001
Model 4[4]	1.05 (1.00, 1.11)	0.06	2.36 (1.38, 4.02)	0.002
Model 5[5]	1.05 (1.00, 1.11)	0.05†	2.40 (1.41, 4.08)	0.001
Model 6[6]	1.05 (1.00, 1.11)	0.05	2.38 (1.40, 4.04)	0.001
Model 7[7]	1.06 (1.00, 1.11)	0.04	2.30 (1.36, 3.91)	0.002
Model 8[8]	1.07 (1.01, 1.22)	0.02	2.63 (1.54, 4.50)	0.001
Cardiovascular mortality				
Model 1[1]	1.08 (1.00, 1.17)	0.05	2.86 (1.26, 6.49)	0.01
Model 2[2]	1.09 (1.00, 1.17)	0.04	3.00 (1.32, 6.85)	0.01
Model 3[3]	1.09 (1.00, 1.18)	0.04	3.10 (1.30, 7.38)	0.01
Model 4[4]	1.08 (1.00, 1.16)	0.06	2.84 (1.24, 6.47)	0.01
Model 5[5]	1.08 (1.00, 1.17)	0.04	3.02 (1.32, 6.91)	0.01
Model 6[6]	1.08 (1.00, 1.17)	0.05	2.91 (1.27, 6.67)	0.01
Model 7[7]	1.08 (1.00, 1.17)	0.05	2.83 (1.24, 6.45)	0.01
Model 8[8]	1.09 (1.02, 1.19)	0.02	3.48 (1.50, 8.10)	0.004
Sudden cardiac death				
Model 1[1]	1.11 (0.98, 1.25)	0.11	4.37 (1.13, 16.93)	0.03
Model 2[2]	1.11 (0.98, 1.25)	0.11	4.46 (1.16, 17.18)	0.03
Model 3[3]	1.11 (0.98, 1.26)	0.09	4.89 (1.15, 20.73)	0.03
Model 4[4]	1.10 (0.98, 1.25)	0.12	4.26 (1.10, 16.48)	0.04
Model 5[5]	1.11 (0.98, 1.25)	0.10	4.50 (1.17, 17.31)	0.03
Model 6[6]	1.09 (0.96, 1.24)	0.17	4.04 (1.03, 15.82)	0.05†
Model 7[7]	1.11 (0.98, 1.26)	0.09	4.35 (1.14, 16.67)	0.03
Model 8[8]	1.11 (0.98, 1.26)	0.11	4.51 (1.15, 17.73)	0.03

† $P < 0.05$

[1] Model 1 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, serum calcium

[2] Model 2 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, serum potassium

[3] Model 3 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, serum magnesium

[4] Model 4 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, dialysate calcium

[5] Model 5 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, dialysate potassium

[6] Model 6 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, intradialytic weight change

[7] Model 7 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, albumin

[8] Model 8 includes the main exposure (either continuous QRS-T angle or dichotomized QRS-T angle), age, sex, race, beta-blocker medication, coronary artery disease, LVMI, QRS duration

Supplementary Table 8. Association of traditional ECG measures with all-cause mortality, cardiovascular mortality, and sudden cardiac death

	All-cause mortality		Cardiovascular mortality		Sudden cardiac death	
	HR (95% CI)	**P**	**HR (95% CI)**	**P**	**HR (95% CI)**	**P**
QRS duration*						
Per 10 ms increase	0.81 (0.68, 0.98)	0.03	0.71 (0.53, 0.94)	0.02	1.01 (0.67, 1.53)	0.94
Heart rate†						
Per 10 bpm increase	1.16 (0.89, 1.50)	0.27	1.20 (0.84, 1.73)	0.32	1.14 (0.67, 1.93)	0.64
LVH by ECG‡						
Absent (n=308)	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Present (n=50)	1.06 (0.55, 2.04)	0.85	0.88 (0.30, 2.63)	0.82	3.06 (0.78, 11.99)	0.11

*Models include the main exposure, age, sex, race, beta-blocker medication, coronary artery disease

† Models include the main exposure, age, sex, race, beta-blocker medication, coronary artery disease, LVMI

‡ Models include the main exposure, age, sex, race, beta-blocker medication, coronary artery disease

Supplemental Figures

Supplementary Figure 1. Measurement of mean QRS-T angle. **A**. Raw unfiltered averaged ECG signal in X, Y, and Z leads. **B**. Reconstructed averaged vectorcardiographic QRS and T loops with detected spatial mean QRS vector and spatial peak T vector. Spatial QRS-T angle is measured as an angle between spatial mean QRS vector and spatial peak T vector.

Supplementary Figure 1.