Implications of Initial Recorded Rhythm on Cardioverter-Defibrillator Insertion and Subsequent All-Cause Mortality in Sudden Cardiac Arrest Survivors

Vincenzo B. Polsinelli, MD, Norman C. Wang, MD, MS, Krishna Kancharla, MD, Aditya Bhonsale, MD, Sandeep K. Jain, MD, and Samir Saba, MD*

Sudden cardiac arrest (SCA) rhythms have been traditionally divided into shockable [ventricular tachycardia (VT)/ventricular fibrillation (VF)] and nonshockable [(asystole (ASY)/pulseless electrical activity (PEA)] rhythms. It is unclear if the specific rhythm has implications on patient management and outcomes. We evaluated 1,433 patients who were admitted with SCA from 2000 to 2012 and were discharged alive. Of those, 1,123 patients had a recorded initial SCA rhythm. Subjects included were >18 years of age, and without an implantable cardioverter-defibrillator (ICD) in place at the time of the event. The likelihood of receiving an ICD for each SCA rhythm and the time to death were analyzed. Of the overall cohort of 1,123 SCA survivors (age of 62 ± 15 years; 39.2% women; 56.3% in-hospital SCA; 83% white; 67% coronary artery disease), 355 (31.6%) received an ICD, and 493 (43.9%) died over a mean follow-up of 3.8 ± 3.2 years. Patients with VF (n = 254, 43.6%) or VT (n = 83, 43.9%) were more likely to receive ICD therapy compared with those with ASY (n = 9, 5.3%) or PEA (n = 9, 4.8%; p <0.001). All-cause mortality was lower in VF patients compared with the other groups (p <0.0001). ICD therapy was associated with lower risk of death in the VF group (hazard ratio [HR] 0.61 [0.45 to 0.83]; p = 0.002) and strong trends toward less mortality in patients with VT (HR 0.64 [0.40 to 1.03]; p = 0.07) and ASY (HR 0.39 [0.12 to 1.31]; p = 0.13) but not in those with PEA (HR 0.93 [0.39 to 2.23]; p = 0.88). In conclusion, long-term survival in post-SCA patients is influenced by initial SCA rhythm. Although SCA survivors with shockable rhythms were more likely to receive ICDs, the ICD was associated with lower risk of death in most patients, including those with ASY. In conclusion, our data suggest that a more detailed SCA rhythm classification has important implications to patient management and long-term survival in this population. **(Am J Cardiol 2019;124:709−714)**

Survivors of sudden cardiac arrest (SCA) are at high risk for recurring lethal arrhythmias. Published guidelines recommend implantable cardioverter-defibrillator (ICD) in patients whose documented initial rhythm is "shockable" (VF or ventricular tachycardia [VT]) as long as there is no reversible underlying cause for the arrhythmia.[1] Although the distinction between shockable (VT/VF) and nonshockable (asystole/pulseless electrical activity [ASY/PEA]) rhythms may be appropriate for the initial management of SCA, the implications of these rhythms on the long-term survival of SCA victims is not fully elucidated. In this large cohort of in-hospital and out-of-hospital SCA survivors without an ICD at the time of presentation, we examine the association of initially recorded rhythm with clinically relevant outcomes. We hypothesized that the initial recorded SCA rhythm will be associated with (1) long-term all-cause mortality, (2) ICD implantation, (3) risk of death among ICD recipients versus nonrecipients within each group by SCA rhythm. Addressing these questions may have important implications to the clinical management of survivors of SCA.

Methods

Survivors of SCA admitted to the hospitals of University of Pittsburgh Medical Center from 2000 to 2012 were included in this analysis. The University of Pittsburgh Medical Center Institutional Review Board approved this study before initiating any research activities and waived the need to obtain informed consent given the retrospective nature of this research. Patients with International Classification of Disease, ninth Revision, Clinical Modification codes for VF (427.41), ventricular flutter (427.42), VT (427.1), and cardiac arrest (427.5), who are 18 years of age or older and who did not have an indwelling ICD at the time of the index SCA were identified from the electronic medical record. A total of 3,426 patient records were identified and were manually reviewed. Of the original 3,426, 1,375 were excluded because manual review demonstrated

The Heart and Vascular Institute and the Department of Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania. Manuscript received March 25, 2019; revised manuscript received and accepted May 16, 2019.

*Corresponding author: Tel: (412) 802-3372; fax: (412) 647-7979.
E-mail address: sabas@upmc.edu (S. Saba).

0002-9149/
https://doi.org/10.1016/j.amjcard.2019.05.059

no actual SCA event, and another 618 were excluded due to duplicate patient entries. Another 310 subjects were excluded from this analysis due to the absence of a recorded SCA rhythm. The remaining 1,123 unique patients constituted the study cohort.

Baseline characteristics including clinical and demographic data were obtained on all patients. Details of the index SCA event such as its location and its association with possible reversible causes were examined. The initial recorded rhythm was ascertained from the electronic medical records including notes from the emergency department, emergency medical services, and hospital SCA response team.

Subjects were followed from the date of the index SCA to the primary outcome of all-cause mortality or until February 20, 2017. Death was ascertained from review of electronic medical records and by interrogating the social security death index database using the updated Social Security Administration Death Master file, for which our healthcare system is exempt from the 3-year delay period by the Social Security Administration. Cases were censored at the date of last follow-up. ICD implantation during the index hospitalization or in follow-up was recorded for all patients. Continuous variables are presented as mean ± standard deviation and are compared between groups using analysis of variance. Discrete variables are presented as frequencies and percentages and are compared using the chi-square test. Independent predictors of receiving an ICD were analyzed using binary logistic regression, adjusting for unbalanced covariates. Time to event (death) was graphed using the Kaplan-Meier method and compared using Cox-proportional hazards first between patients grouped by initial recorded SCA rhythm and second within each rhythm group between ICD recipients and nonrecipients. After ascertaining that the proportional hazards assumption was satisfied, independent predictors of mortality were assessed using Cox regression models in which all baseline characteristics with a 2-sided p value of <0.05 were included. Statistical significance was defined as a 2-sided p value of <0.05. All statistical analyses were performed on Stata software version 12.1 (Statacorp, College Station, Texas).

Results

Baseline characteristics from initially recorded rhythms are detailed in Table 1. The study cohort consisted mostly of white men with a high prevalence of coronary artery disease, myocardial infarction, congestive heart failure, and atrial fibrillation, as well as other medical co-morbidities including hypertension, diabetes, chronic obstructive pulmonary disease, and chronic kidney disease. The mean left ventricular ejection fraction was mildly reduced. Slightly over half of the SCA events occurred in a hospital setting and a large proportion of patients had evidence of myocardial infarction, or of either metabolic or electrolyte abnormalities at the time of the event.

The most commonly recorded SCA rhythm in our cohort was VF. There were important baseline differences noted by initial documented rhythm. Compared with VF or VT patients, those with ASY or PEA were more likely to be women, non-white and had lower prevalence of coronary artery disease, chronic obstructive pulmonary disease, and chronic kidney disease. They also had a more preserved left ventricular ejection fraction. Patients with VT had longer PR, QRS, QT, and QTC intervals on surface electrocardiogram compared with patients in the other rhythm groups. Also, a greater proportion of patients with ASY or PEA suffered an in-hospital SCA and demonstrated evidence of significant metabolic abnormalities around the index event. Their mean duration of index hospitalization was also longer than that of patients with VT or VF.

Over a mean follow-up of 3.8 ± 3.2 years, 355 (32%) received an ICD. Patients with VF or VT had a markedly greater proportion of ICD implantation compared with patients with ASY or PEA (Figure 1). The proportion of patients receiving an ICD during the index hospitalization or during follow-up was 43.6% for VF, 44.9% for VT, 5.3% for ASY, and 4.8% for PEA ($p<0.001$ for VT/VF compared with ASY/PEA). Compared with ICD nonrecipients, left ventricular ejection fraction was lower in ICD recipients with an initial recorded rhythm of VF (44.4 ± 14.8 vs 37.8 ± 16.2, $p<0.0001$), and ASY (50.4 ± 13.7 vs 32.9 ± 18.1, $p=0.0016$) but not VT or PEA. (Supplemental Table 1) Using binary logistic regression, independent predictors of receiving an ICD included the presenting shockable rhythm, the absence of coronary artery disease, and an out-of-hospital SCA (Table 2).

Over a mean follow-up of 3.8 ± 3.2 years, 83 (7.4%) of patients received an appropriate ICD shock and 493 (44%) patients died. Appropriate ICD shocks were experienced in 57 of 254 (22%) patients presenting with VF, in 22 of 83 (26%) patients presenting with VT, in 1 of 9 (11%) patients presenting with ASY, and in 3 of 9 (33%) patients presenting with PEA. We examined the adjusted all-cause mortality among the study cohort stratified initially by recorded rhythm using Cox-proportional hazards model (Table 3). Among the 4 rhythm cohorts, VF patients were less likely to die compared with VT, ASY, or PEA patients (Figure 2, Table 3). There were no observed differences in outcomes between the other 3 groups. Next, we examined all-cause mortality in subjects with and without ICD implantation stratified by presenting rhythm (Figure 2). Among patients who did not receive an ICD, patients with VF were less likely to die compared with VT (hazard ratio [HR] 1.77 [1.26 to 2.48]; $p=0.001$), ASY (HR 1.43 [1.06 to 1.92]; $p=0.019$), or PEA (HR 1.72 [1.29 to 2.28]; $p<0.001$) patients. Among patients who received an ICD, patients with PEA (HR 3.08 [1.27 to 7.45]; $p=0.13$) were more likely to die compared with VF, and there was no difference in all-cause mortality between patients with VF, VT (HR 1.49 [0.99 to 2.26]; $p=0.058$), and ASY (HR 0.95 [0.29 to 3.09]; $p=0.93$; Figure 2). We examined all-cause mortality in subjects who experienced SCA in-hospital compared with out-of-hospital among each presenting rhythm subgroup. In subjects with ASY, subjects with an in-hospital SCA compared with out-of-hospital SCA observed a lower risk of death (HR 0.55 [0.32 to 0.93]; $p=0.027$). No differences were observed in VF (HR 1.02 [0.75 to 1.39]; $p=0.88$), VT (HR 0.96 [0.59 to 1.54]; $p=0.86$), or PEA (HR 0.78 [0.52 to 1.19]; $p=0.25$). Finally, we examined the survival benefit of ICD implantation on long-term all-cause mortality within each presenting rhythm group (Figure 3).

Table 1
Baseline characteristics of sudden cardiac arrest survivors by presenting rhythm

Variables	n	Overall (n = 1,123)	VF (n = 583)	VT (n = 185)	Asystole (n = 169)	PEA (n = 186)	p value
Age (years)	1123	61.7 ± 15.4	61.6 ± 14.1	63.1 ± 15.8	61.6 ± 17.7	60.9 ± 16.9	0.55
Women	1123	440 (39.2%)	211 (36.2%)	60 (32.4%)	74 (43.8%)	95 (51.1%)	<0.001
Non-white	1123	191 (17.0%)	85 (14.6%)	25 (13.5%)	37 (21.9%)	44 (23.7%)	0.005
Any coronary artery disease	1123	750 (66.8%)	460 (78.9%)	135 (73.0%)	78 (46.2%)	77 (41.4%)	<0.001
Prior myocardial infarction	1123	586 (52.2%)	389 (66.7%)	98 (53.0%)	50 (29.6%)	49 (26.3%)	<0.001
Prior CABG	1123	167 (14.9%)	93 (16.0%)	37 (20.0%)	20 (11.8%)	17 (9.1%)	0.015
Prior PCI	1123	136 (12.1%)	94 (16.1%)	16 (8.7%)	11 (6.5%)	15 (8.1%)	<0.001
Congestive heart failure	1123	374 (33.3%)	202 (34.7%)	67 (36.2%)	52 (30.8%)	53 (28.5%)	0.31
Valve disease	1123	209 (18.6%)	101 (17.3%)	41 (22.2%)	38 (22.5%)	29 (15.6%)	0.17
Pre-SCA beta-blocker	1096	443 (40.4%)	244 (42.7%)	70 (39.3%)	60 (36.4%)	69 (37.9%)	0.398
Class I or III antiarrhythmic	1123	21 (2%)	11 (2%)	6 (3%)	4 (2%)	0 (0%)	0.29
Atrial Fibrillation	1123	335 (29.8%)	159 (27.3%)	70 (37.8%)	57 (33.7%)	49 (26.3%)	0.02
Ejection fraction (%)	895	44. ± 16	42 ± 16	42 ± 17	49 ± 14	52 ± 14	<0.0001
NYHA	135	2.0 ± 0.9	1.8 ± 0.9	1.9 ± 0.9	2.1 ± 0.9	2.4 ± 0.8	0.07
NYHA class							
I	52	52 (38.5%)	30 (46.9%)	9 (40.9%)	9 (33.3%)	4 (18.2)	0.18
II	37	37 (27.4%)	17 (26.6%)	8 (36.4%)	6 (22.2%)	6 (27.3)	
III	42	42 (31.1%)	15 (23.4%)	4 (18.2%)	11 (40.7%)	12 (54.6)	
IV	4	4 (3.0%)	2 (3.1%)	1 (4.6%)	1 (3.7%)	0 (0.0%)	
Diabetes mellitus	1123	356 (31.7%)	157 (26.9%)	65 (35.1%)	65 (38.5%)	69 (37.1%)	0.004
Hypertension	1123	695 (61.9%)	368 (63.1%)	110 (59.5%)	90 (53.3%)	127 (68.3%)	0.024
Peripheral vascular disease	1123	119 (10.6%)	60 (10.3%)	20 (10.8%)	20 (11.8%)	19 (10.2%)	0.95
Chronic pulmonary disease	1123	351 (31.3%)	155 (26.6%)	61 (33.0%)	58 (34.3%)	77 (41.4%)	0.001
Chronic kidney disease or dialysis	1123	180 (16.0%)	71 (12.2%)	30 (16.2%)	32 (18.9%)	47 (25.3%)	<0.001
Moderate/severe liver disease	1123	14 (1.3%)	5 (0.9%)	1 (0.5%)	6 (3.6%)	2 (1.1%)	0.032
Dementia	1123	35 (3.1%)	11 (1.9%)	7 (3.8%)	8 (4.7%)	9 (4.8%)	0.090
Malignancy	1123	123 (11.0%)	52 (8.9%)	22 (11.9%)	24 (14.2%)	25 (13.4%)	0.13
Body mass index (kg/m^2)	1011	30.0 ± 7.9	30.0 ± 7.9	30.0 ± 7.0	29.8 ± 7.5	30.0 ± 8.8	0.99
Charlson co-morbidity index	1123	2.7 ± 2.3	2.4 ± 2.1	2.8 ± 2.4	3.0 ± 2.6	2.9 ± 2.5	0.0121
PR interval (ms)	938	169.0 ± 42.2	167.5 ± 36.8	178.5 ± 54.6	177.8 ± 51.3	157.3 ± 32.0	<0.0001
QRS duration (ms)	1082	106.9 ± 31.5	106.4 ± 28.3	118.5 ± 41.1	101.6 ± 25.5	102.0 ± 32.7	<0.0001
QT interval (ms)	1081	402.2 ± 71.3	402.8 ± 66.5	414.6 ± 88.3	400.0 ± 66.8	390.2 ± 72.4	0.0148
QTc interval (ms)	1082	474.3 ± 53.9	472.0 ± 53.7	486.6 ± 58.7	466.1 ± 50.7	476.9 ± 50.5	0.0022
Serum potassium (mEq/L)	1112	4.2 ± 1.2	4.0 ± 0.9	4.2 ± 2.1	4.4 ± 1.0	4.4 ± 1.1	0.0001
Serum magnesium (mEq/L)	1066	2.0 ± 0.5	2.0 ± 0.5	2.1 ± 0.5	2.1 ± 0.5	2.0 ± 0.6	0.46
Serum bicarbonate (mmol/L)	1082	23.5 ± 5.4	23.3 ± 5.0	23.6 ± 4.9	23.5 ± 5.9	24.1 ± 6.3	0.35
Troponin I (μg/L)	946	11.4±44.2	17.0±54.1	11.2±44.9	1.5±7.4	1.6±8.6	0.0001
Creatinine phosphokinase-MB (μg/L)	310	57.7 ± 132.8	66.0 ± 148.3	68.0 ± 134.9	23.5 ± 66.6	34.8 ± 79.3	0.22
Aspirin	462	462 (41%)	246 (42%)	66 (36%)	76 (45%)	74 (40%)	0.43
Beta-blockers	443	443 (39%)	244 (42%)	70 (38%)	60 (36%)	69 (37%)	0.40
Class I or III antiarrhythmic drugs	21	21 (2%)	11 (2%)	6 (3%)	4 (2%)	0 (0%)	0.29
Heart rate (beats per minute)	1083	88.9 ± 25.7	87.2 ± 23.8	90.3 ± 28.0	87.6 ± 29.1	94.0 ± 25.3	0.0143
Systolic blood pressure (mm Hg)	1092	126.5 ± 31.1	127.7 ± 30.3	128.1 ± 28.3	126.5 ± 34.0	121.5 ± 33.2	0.11
Diastolic blood pressure (mm Hg)	1081	70.8 ± 20.9	72.5 ± 20.8	70.6 ± 20.1	67.1 ± 19.1	69.0 ± 23.1	0.0168
Location (in-hospital)	1123	632 (56.3%)	281 (48.2%)	106 (57.3%)	125 (74.0%)	120 (64.5%)	<0.001
Significant electrolyte abnormality	1123	194 (17.3%)	95 (16.3%)	32 (17.3%)	27 (16.0%)	40 (21.5%)	0.40
Significant metabolic abnormality	1123	151 (13.5%)	65 (11.2%)	19 (10.3%)	30 (17.8%)	37 (19.9%)	0.004
Reversible and correctable cause	1123	652(58.1%)	390(66.9%)	104(56.2%)	77(45.6%)	81(43.6%)	<0.001
Cath evidence of acute MI	1123	402 (35.8%)	303 (52.0%)	70 (37.8%)	22 (13.0%)	7 (3.8%)	<0.001
Length of stay (days)	1123	15.1 ± 16.0	12.5 ± 11.9	16.7 ± 18.7	17.7 ± 21.5	19.5 ± 16.7	<0.0001

CABG = coronary artery bypass graft surgery; MI = myocardial infarction; NYHA = New York Heart Association class; PCI = percutaneous coronary intervention; SCA = sudden cardiac arrest.

Significant benefit of ICD implantation was observed in those patients presenting with VF (HR 0.61 [0.45 to 0.83]; p = 0.002). There were nonsignificant trends toward survival in the presence of an ICD noted in VT (HR 0.64 [0.40 to 1.03]; p = 0.066) and ASY (HR 0.39 [0.12 to 1.31]; p = 0.128) patients but not in those with PEA (HR 0.93 [0.39 to 2.23]; p = 0.876).

Discussion

Our data demonstrate that long-term mortality in post-SCA survivors may be influenced by initial SCA rhythm and that ICD therapy is as expected more prescribed in patients with "shockable" rhythms. We found that ICD therapy is associated with lower risk of death in patients presenting with VT, VF, and a nonsignificant trend in those

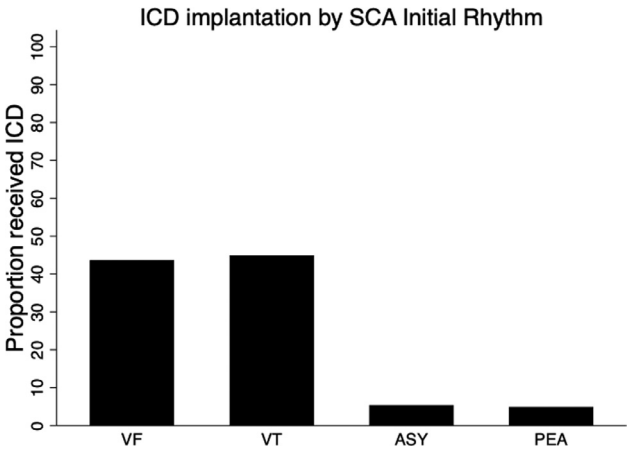

Figure 1. Proportion of ICD implantation by initial SCA rhythm.

Table 2
Independent predictors of receiving ICD therapy in SCA survivors

	Adjusted OR (95% CI)	p Value
Initial SCA rhythm		
Ventricular fibrillation	*Ref.*	
Ventricular tachycardia	1.12 (0.79−1.58)	0.54
Asystole	0.08 (0.04−0.16)	<0.001
Pulseless electrical activity	0.07 (0.03−0.14)	<0.001
Sex (ref = female)	1.30 (0.96−1.76)	0.085
Race (ref = white)	0.89 (0.60−1.33)	0.56
Coronary artery disease	0.66 (0.46−0.95)	0.026
Atrial fibrillation	1.13 (0.82−1.55)	0.47
Diabetes mellitus	0.98 (0.69−1.41)	0.92
Chronic pulmonary disease	1.09 (0.76−1.56)	0.64
Chronic kidney disease	0.74 (0.41−1.34)	0.32
Dementia	0.66 (0.25−1.76)	0.41
Charlson co-morbidity index	1.02 (0.91−1.14)	0.71
Significant metabolic abnormality	0.71 (0.45−1.13)	0.15
SCA location (ref = out-of-hospital)	0.42 (0.32−0.56)	<0.001
Admission duration	1.00 (0.99−1.01)	0.71
Hypertension	1.11 (0.82−1.50)	0.51
Liver disease	1.75 (0.41−7.41)	0.45

Table 3
Independent predictors of all-cause mortality in SCA survivors

	HR (95% CI)	p value
Initial SCA rhythm		
Ventricular fibrillation	*Ref.*	*Ref.*
Ventricular tachycardia	1.60 (1.24−2.07)	<0.001
Asystole	1.54 (1.17−2.02)	0.002
Pulseless electrical activity	1.73 (1.33−2.26)	<0.001
Post-SCA ICD	0.60 (0.47−0.76)	<0.001
Sex (ref = female)	0.87 (0.73−1.05)	0.15
Race (ref = white)	1.27 (1.00−1.60)	0.048
Coronary artery disease	0.89 (0.72−1.10)	0.29
Atrial fibrillation	1.72 (1.42−2.07)	<0.001
Diabetes mellitus	1.28 (1.04−1.56)	0.018
Chronic pulmonary disease	1.12 (0.91−1.36)	0.28
Chronic kidney disease	1.40 (1.06−1.84)	0.018
Dementia	1.64 (1.09−2.46)	0.017
Charlson co-morbidity index	1.19 (1.13−1.26)	<0.001
Metabolic abnormality	1.28 (1.00−1.63)	0.046
SCA location (ref = out-of-hospital)	0.86 (0.71−1.05)	0.15
Admission duration	1.00 (0.99−1.00)	0.6
Hypertension	1.02 (0.84−1.24)	0.81
Liver disease	1.16 (0.62−2.18)	0.63

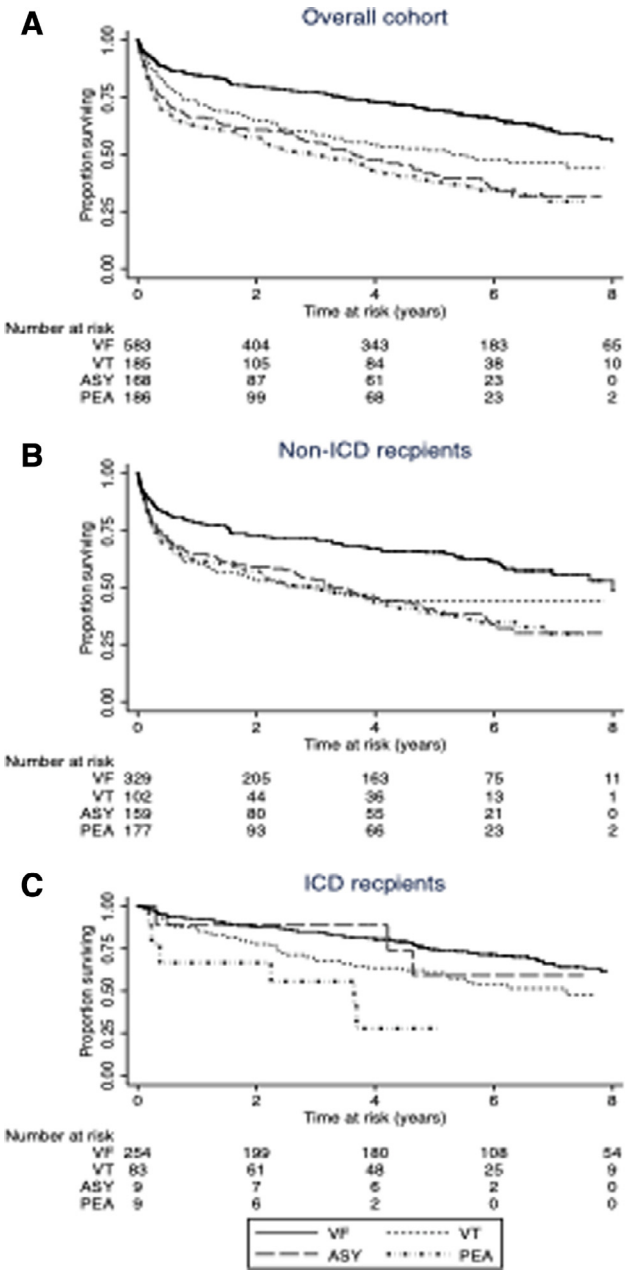

Figure 2. Kaplan-Meier survival curve of all-cause mortality stratified by initial recorded rhythm for *(A)* overall cohort, *(B)*non-ICD recipients, *(C)* ICD recipients.

with ASY. Only in patients whose initial SCA rhythm is PEA, was ICD therapy not associated with lower risk of death. These data are important because although traditional separation of rhythm into shockable and nonshockable may be suitable for immediate management during SCA, it may not be appropriate for the long-term decision making around ICD therapy. Our data, if confirmed prospectively, may have significant implications for the management of SCA survivors.

According to our data, patients presenting with VF have a lower risk of death than those presenting with VT, ASY, or PEA. The finding of worse survival in PEA and ASY patients compared with VF is consistent with other studies

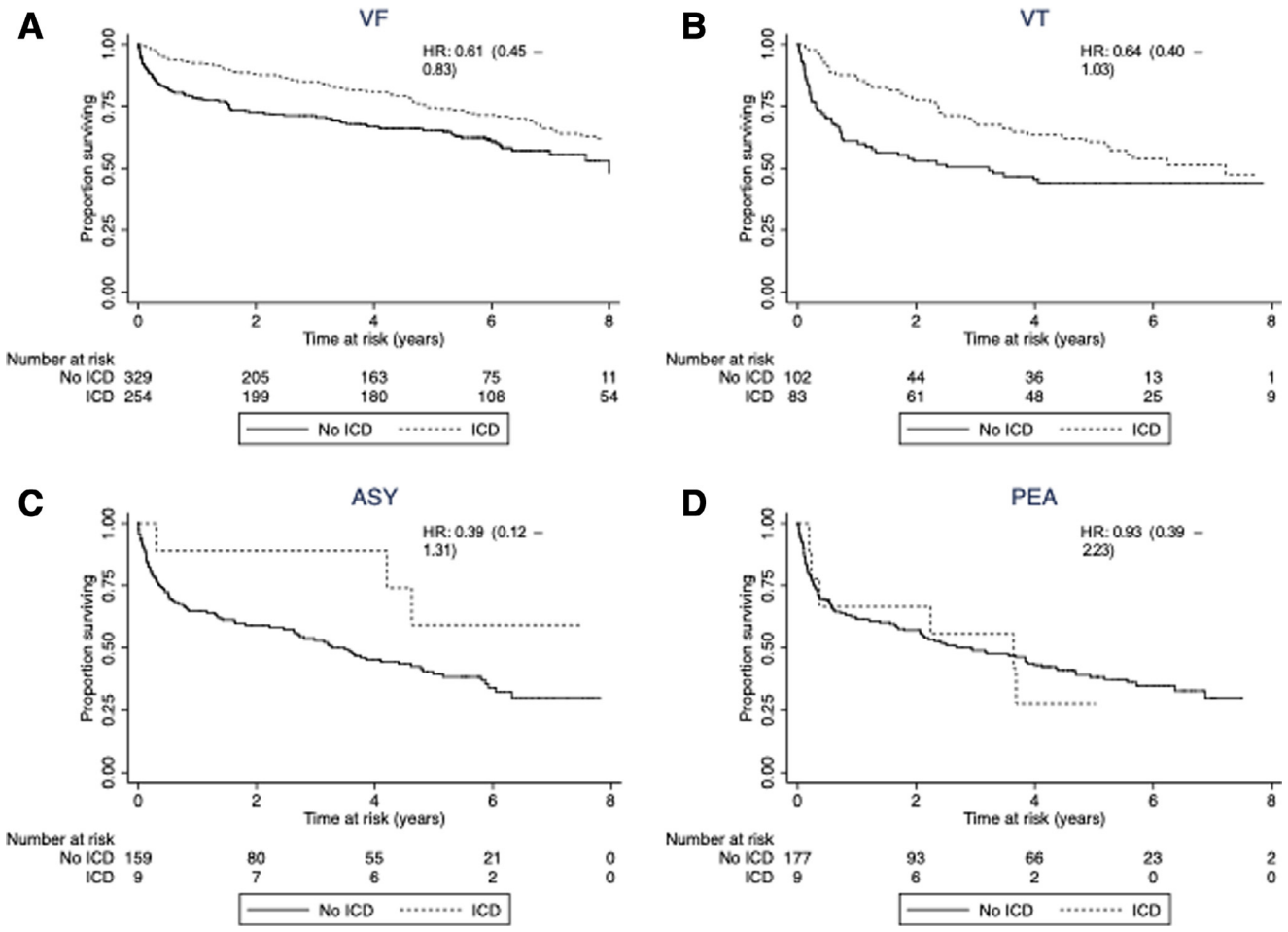

Figure 3. Kaplan-Meier survival curve of all-cause mortality stratified by ICD placement in *(A)* VF, *(B)* VT, *(C)* Asystole, *(D)* PEA.

and is best explained by ASY, which is lack of autonomic electrical activation of the conduction system, and PEA, a failure of meaningful cardiac output in the presence of an organized electrical rhythm, usually inflict patients with many co-morbidities which end-up limiting survival.[2] One possibility that may explain the lower risk of death in VF compared with VT patients is that VT is a more organized rhythm requiring the presence of myocardia scar to sustain reentry, whereas VF is usually related to metabolic derangements or global ischemia, both of which can be reversed whereas ventricular scarring is fixed. VF is commonly the mechanism of ischemia-related SCA. This is supported by autopsy studies which demonstrate shockable rhythms are strongly associated with ischemic heart disease.[3,4] Moreover, in a study of SCA during cardiac monitoring, primary VF was highly associated with the presence of acute coronary syndromes, and VT degenerating to VF was the second most common rhythm seen in patients suffering an acute coronary event. Acute coronary syndrome was not observed in patients with primary VT.[5] Although several studies had previously demonstrated more favorable short-term outcomes in PEA compared with ASY patients, our data suggest no difference in the long-term prognosis between these 2 groups.[6,7]

Overall, our data suggest that about one-third of survivors of SCA receive an ICD, which is consistent with other publications.[8] In our cohort, we observed significantly greater prevalence of ICD utilization among subjects with VT or VF compared with those with ASY or PEA. This likely reflects ICDs, which are shocking devices are intuitively more prescribed for shockable rhythms. It is also a reflection of the original clinical trials for secondary prevention of SCA which demonstrated a survival benefit with the ICD in the context of VF or VT SCA.[9–11] Among the 4 rhythm groups, we observed lower risk of death with ICD therapy in VF and VT. However, we observed a trend of lower risk of death with ICD therapy in ASY but not in PEA patients. These findings may be explained in several ways. In patients with VF or VT, ICD therapy is well demonstrated and is likely meant to abort a future recurrence of the shockable rhythm.[12,13] Among our subjects with ASY, we found the group that received ICDs had a significantly lower EF, which may have provided the impetus for ICD implantation. Furthermore, it is believed that many subjects who present with ASY had likely degenerated from VF or VT prior by the time emergency medical services arrived on the scene and the first rhythm was recorded.[14] Therefore, it is likely that a subset of patients with ASY who received

an ICD, may benefit from defibrillation of a shockable rhythm earlier in the course of their arrest. Also, because ASY is a failure of automatic electrical activation of the cardiac conduction system, another possible mechanism of benefit in survivors of ASY may be that all transvenous ICDs are pacemakers and potentially effective therapy for ASY. Thus, ICD therapy may have a role in the long-term management of SCA survivors who present with ASY.

Our study has limitations. It is a single-center, retrospective analysis and therefore may be subject to bias. We have attempted to limit the bias by adjusting for all unbalanced covariates which may influence the primary outcome of all-cause mortality and by including all survivors of SCA who had documented initial rhythm at the time of the index event from 25 hospitals within the University of Pittsburgh Medical Center network, which spans a wide area of western Pennsylvania including rural community hospitals and urban tertiary centers. Still, our results may not be extrapolated to other patient populations cared for in different settings. Data regarding ICD settings was not available, and procedures for selecting and programming ICDs were not standardized, which may have affected outcomes.[15,16]

Our data demonstrate that an initial recorded rhythm of VF is predictive of lower risk of death after SCA, that ICD therapy is associated with lower risk of death in patients with initial rhythm of VF or VT, but not PEA. Patients with ASY exhibited a strong trend toward less mortality with the ICD but this did not reach statistical significance. ICD therapy is more prescribed in subjects with a shockable rhythm. Although common practice is to separate SCA victims into those with "shockable" versus "nonshockable" rhythms, our data suggest that a more specific rhythm identification may have important implications to the management and long-term prognosis of SCA survivors.

Conflict of interest statement

The authors have no conflict of interest with regards to the subject matter of this study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.amjcard.2019.05.059.

1. Al-Khatib SM, Stevenson WG, Ackerman MJ, Bryant WJ, Callans DJ, Curtis AB, Deal BJ, Dickfeld T, Field ME, Fonarow GC, Gillis AM, Granger CB, Hammill SC, Hlatky MA, Joglar JA, Kay GN, Matlock DD, Myerburg RJ, Page RL. 2017 AHA/ACC/HRS Guideline for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death: executive summary. *Circulation* 2018;138:e210–e271.
2. Teodorescu C, Reinier K, Dervan C, Uy-Evanado A, Samara M, Mariani R, Gunson K, Jui J, Chugh SS. Factors associated with pulseless electric activity versus ventricular fibrillation: the Oregon Sudden Unexpected Death Study. *Circulation* 2010. CIRCULATIONAHA.110.966333.
3. Tseng ZH, Olgin JE, Vittinghoff E, Ursell PC, Kim AS, Sporer K, Yeh C, Colburn B, Clark NM, Khan R. Prospective countywide surveillance and autopsy characterization of sudden cardiac death: POST SCD Study. *Circulation* 2018;137:2689–2700.
4. Kauppila JP, Hantula A, Kortelainen M-L, Pakanen L, Perkiömäki J, Martikainen M, Huikuri HV, Junttila MJ. Association of initial recorded rhythm and underlying cardiac disease in sudden cardiac arrest. *Resuscitation* 2018;122:76–78.
5. Watanabe E, Tanabe T, Osaka M, Chishaki A, Takase B, Niwano S, Watanabe I, Sugi K, Katoh T, Takayanagi K. Sudden cardiac arrest recorded during Holter monitoring: prevalence, antecedent electrical events, and outcomes. *Heart Rhythm* 2014;11:1418–1425.
6. Bergström M, Schmidbauer S, Herlitz J, Rawshani A, Friberg H. Pulseless electrical activity is associated with improved survival in out-of-hospital cardiac arrest with initial non-shockable rhythm. *Resuscitation* 2018;133:147–152.
7. Fukuda T, Ohashi-Fukuda N, Matsubara T, Doi K, Kitsuta Y, Nakajima S, Yahagi N. Association of initial rhythm with neurologically favorable survival in non-shockable out-of-hospital cardiac arrest without a bystander witness or bystander cardiopulmonary resuscitation. *Eur J Intern Med* 2016;30:61–67.
8. Adabag S, Hodgson L, Garcia S, Anand V, Frascone R, Conterato M, Lick C, Wesley K, Mahoney B, Yannopoulos D. Outcomes of sudden cardiac arrest in a state-wide integrated resuscitation program: results from the Minnesota Resuscitation Consortium. *Resuscitation* 2017;110:95–100.
9. Kuck K-H, Cappato R, Siebels Jr., Rüppel R. Randomized comparison of antiarrhythmic drug therapy with implantable defibrillators in patients resuscitated from cardiac arrest: the Cardiac Arrest Study Hamburg (CASH). *Circulation* 2000;102:748–754.
10. Investigators AvID. A comparison of antiarrhythmic-drug therapy with implantable defibrillators in patients resuscitated from near-fatal ventricular arrhythmias. *N Engl J Med* 1997;337:1576–1584.
11. Connolly SJ, Gent M, Roberts RS, Dorian P, Roy D, Sheldon RS, Mitchell LB, Green MS, Klein GJ, O'brien B. Canadian Implantable Defibrillator Study (CIDS) a randomized trial of the implantable cardioverter defibrillator against amiodarone. *Circulation* 2000;101:1297–1302.
12. Link MS, Atkins DL, Passman RS, Halperin HR, Samson RA, White RD, Cudnik MT, Berg MD, Kudenchuk PJ, Kerber RE. Part 6: electrical therapies: automated external defibrillators, defibrillation, cardioversion, and pacing: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2010;122:S706–S719.
13. Baker PW, Conway J, Cotton C, Ashby DT, Smyth J, Woodman RJ, Grantham H, Investigators C. Defibrillation or cardiopulmonary resuscitation first for patients with out-of-hospital cardiac arrests found by paramedics to be in ventricular fibrillation? A randomised control trial. *Resuscitation* 2008;79:424–431.
14. Castellanos RJMaA. Cardiac arrest and sudden cardiac death. In: Douglas L, Mann DPZ, Peter Libby, Robert O, Bonow, Eugene Braunwald, eds. Braunwald's Heart Disease, 838. Philadelphia: Elsevier Saunders; 2015.
15. Kloppe A, Proclemer A, Arenal A, Lunati M, Martinez Ferrer JB, Hersi A, Gulaj M, Wijffels MC, Santi E, Manotta L, Mangoni L, Gasparini M. Efficacy of long detection interval implantable cardioverter-defibrillator settings in secondary prevention population: data from the Avoid Delivering Therapies for Nonsustained Arrhythmias in ICD Patients III (ADVANCE III) trial. *Circulation* 2014;130:308–314.
16. Stroobandt RX, Duytschaever MF, Strisciuglio T, Van Heuverswyn FE, Timmers L, De Pooter J, Knecht S, Vandekerckhove YR, Kucher A, Tavernier RH. Failure to detect life-threatening arrhythmias in ICDs using single-chamber detection criteria. *Pacing clin Electrophysiol* 2019;42:583–594.