

CHA₂DS₂-VASC score predicts coronary artery disease progression and mortality after ventricular arrhythmia in patients with implantable cardioverter-defibrillator



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ABSTRACT

Aim: The CHA₂DS₂-VASC score has expanded its use beyond the initial purpose of predicting the risk of stroke in patients with atrial fibrillation. We aimed to investigate the value of the CHA₂DS₂-VASC score as a risk assessment tool to predict relevant coronary artery disease (CAD) leading to percutaneous coronary intervention (PCI), and all-cause mortality after detected ventricular arrhythmia (VA) in patients with an Implantable Cardioverter-Defibrillator (ICD).

Methods: A total of 183 ICD-patients who underwent coronary angiography after VA were included and classified according to their CHA₂DS₂-VASC score in a low(1-3), intermediate(4-5) and high(6-8) score group. We evaluated the predictive value of CHA₂DS₂-VASC score for the presence of relevant CAD leading to percutaneous coronary intervention (PCI), as well as late all-cause mortality.

Results: A total of 60 patients (32.8%) had significant CAD and underwent successful PCI. After adjustment for relevant parameters such as ischemic cardiomyopathy, angina pectoris, left ventricular ejection fraction, CHA₂DS₂-VASC score remained the only independent predictor of CAD leading to PCI [HR 1.73 (1.07–2.80)]. The Area under curve was 0.64 (0.56–72, p = 0.002). Kaplan-Meier analysis and log-rank showed an increased three-year mortality of ICD-patients with an intermediate or high score after VA (p = 0.003). Multivariate cox-regression analysis revealed that CHA₂DS₂-VASC score was also independently associated with all-cause mortality following adjustment for clinically relevant variables (HR 2.20, 1.17–4.14).

Conclusions: CHA₂DS₂-VASC score can be a predictor of CAD leading to PCI in ICD-patients after VA. ICD-Patients with a high score have an increased risk for reduced three-year all-cause mortality after VA.

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1. Introduction

Ventricular arrhythmias (VA) are responsible for most cases of sudden cardiac death and are important contributors to mortality and morbidity in patients with coronary artery disease (CAD) [1].

Abbreviations: AF, Atrial fibrillation; CABG, Coronary artery bypass graft; CAD, Coronary artery disease; CK-MB, Creatine Kinase MB Isoenzyme; ICD, Implantable Cardioverter-Defibrillator; LDL, Low-Density Lipoprotein; LVEF, Left Ventricular Ejection Fraction; PCI, Percutaneous Coronary Intervention; VA, Ventricular Arrhythmia; VF, Ventricular Fibrillation; VT, Ventricular Tachycardia.

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Especially in patients with CAD, VA is a feared complication and accounts for the majority of deaths occurring in the acute phase of an ischemic event. In patients with an Implantable Cardioverter-Defibrillator (ICD), the ICD serves as 'safety net' against life threatening arrhythmias and represents an effective tool terminating VA [2]. An ICD interrogation can be performed to detect VA and distinguish between ventricular tachycardia (VT) and ventricular fibrillation (VF) [3]. As VA can be a sentinel marker of acute or chronic myocardial ischemia, coronary angiography is therefore frequently used to rule out the presence of significant coronary artery stenosis and/or myocardial infarction in VA patients [4,5]. The decision for an invasive strategy after VA in ICD-patients can be difficult, especially in ICD-patients who are stable, without symptoms and with preserved functional capacity. The CHA₂DS₂-VASC score is a pivotal instrument to assess

the risk of developing cardiac thrombo-embolism and to guide anticoagulant therapy in patients with atrial fibrillation (AF) [6]. The score also demonstrated its prognostic ability in predicting death and cardiovascular hospitalizations among patients with or without AF as well as in various cardiovascular conditions e.g. acute coronary syndrome [7–11].

The aim of the current study was to investigate the value of the CHA₂DS₂-VASC score as a risk assessment tool to predict significant CAD leading to an invasive reperfusion therapy after detected VA in ICD-patients. We also evaluated its predicting ability for all-cause mortality after detected VA.

2. Methods

2.1. Study population

We retrospectively enrolled 183 patients with an ICD who experienced ventricular arrhythmia (VA) leading to a coronary angiography between 2005 and 2018. The selection process was performed as follows: we scanned our electronic hospital information system for ICD patients who got a coronary angiography, with the help of German International Statistical Classification of Diseases. In the resulting patient-list with more than eight thousand patients, we checked manually, if the patient had a VA prior to coronary angiography, and if VA had an impact in the decision-making of the procedure. VA was detected by ICD interrogation at our center, premature ventricular beats were not included. All patients underwent coronary angiography within the next three months after VA detection, followed by percutaneous coronary intervention (PCI) in cases with significant CAD. Eight patients had a non-invasive ischemia testing performed prior to coronary angiography. Patients had provided informed consent for the procedures and all relevant, medically appropriate care that should be provided in emergencies. All data were fully anonymised before access and analysis. ICD implantation was performed for primary (n = 66/183) or secondary prevention (n = 117/183) [12]. Primary prevention was divided into ischemic (n = 25/66) or non-ischemic aetiology (n = 41/66) [dilated cardiomyopathy (n = 40) or hypertrophic obstructive cardiomyopathy (n = 1)]. As for secondary prevention, the majority of patients had an ischemic cardiomyopathy (n = 105/117), while 9/117 patients had a dilated cardiomyopathy, one patient had a hypertrophic obstructive cardiomyopathy, and two patients had none of these. Of ICD-patients with secondary prevention, 39/117 (33%) patients had a cardiac arrest with cardiopulmonary resuscitation prior to ICD implantation.

2.2. CHA₂DS₂-VASC score

CHA₂DS₂-VASC score [applied according to current standards [13]] was calculated for each patient by assigning 1 point each for congestive heart failure, history of hypertension, age between 65 and 74 years, diabetes mellitus, vascular disease (coronary artery or peripheral artery disease), female gender and 2 points each for history of stroke/transient ischemic attack or an age of 75 years or older. Patients were categorized in a low, intermediate and high CHA₂DS₂-VASC score group. For the attribution of points, the low and high score groups should not exceed one-third of the total cohort.

2.3. Study end points and follow-up

Primary endpoint was the presence of relevant CAD which was revealed in the coronary angiography and leading to PCI. Hereby, revascularization was performed in line with European guidelines

[14]. Secondary endpoint was defined as all-cause mortality within 3-year follow-up. Patients were scheduled for regular visits for ICD interrogation every three to twelve months. Patients missing these visits were followed-up via a telephone interview.

2.4. Statistical analysis

Statistical analysis was conducted with SPSS Statistics software version 24.0.0.0 (IBM, Armonk, NY, USA). Data are presented as mean ± standard deviation if normally distributed or as median and interquartile range (quartile 1–quartile 3) if not normally distributed. Normal distribution were tested with the use of the Kolmogorov-Smirnov test. For continuous variables Student's *t*-test or Mann-Whitney *U* test was used comparing two groups. Differences between more than two groups were compared by ANOVA or the Kruskal–Wallis test. Chi-square test was performed for analysis of categorical variables. The Kaplan–Meier method and the log rank test were used for presenting the survival rate and determine statistical differences. Univariate and multivariate logistic regression analysis was used to derive independent predictors of the primary endpoint. For multivariate analysis, we included parameter which were known to be associated with relevant CAD and/or showed significance in the univariate analysis. Regarding the primary endpoint these parameters were: history of smoking, ischemic cardiomyopathy, ICD as secondary prevention, left ventricular ejection fraction, renal function, low-density lipoprotein and symptomatic burden. Receiver operating characteristic (ROC) curves were constructed to confirm and compare the predicting ability or parameters. Multivariate Cox regression analysis was performed for independent predictors of 3-year mortality. For the secondary endpoint we focused on known mortality risk factors rather than parameters associated with CAD and included parameters including age, history of smoking, chronic obstructive pulmonary disease, ischemic cardiomyopathy, body-mass-index, left ventricular ejection fraction, renal function and atrial fibrillation. P-value of < 0.05 was considered to be statistically significant.

3. Results

A total of 183 patients with an ICD who underwent coronary angiography after VA were included into final analysis. The mean age of our study cohort was 71 ± 10.5; 21 patients (11.5%) were of female gender; median Left ventricular ejection fraction (LVEF) was 33% (25–44%). Seventy-four patients (40.4%) presented with angina pectoris, 20 (10.9%) had palpitations, 38 (20.8%) showed dizziness, 28 (15.3%) presented with a syncope, and 67 patients (36.6%) had no specific symptoms. VT in VF zone was detected in 71 of 183 (39%) patients. ICD-treatment included shocks in 116 (63%) patients and antitachycardia pacing in 95 (52%) patients. The indication for ICD in this collective was primary prevention in 36% of cases. Ischemic heart disease was present in 71% of patients. Follow-up data were available for 159 (87%) patients, with a mean follow-up duration of 1124 ± 950 days. Therefore 24 patients were not included for analysis of the secondary endpoint.

Of 183 ICD-patients undergoing coronary angiography after VA, a total of 60 patients (32.8%) showed CAD leading to PCI. Median duration of VA-detection until coronary angiography was 3 [1–12] days. All 60 patients undergoing PCI had a history of vascular disease (p < 0.001); 51 of 60 (85%) had a prior diagnosed ischemic cardiomyopathy (p = 0.004). Mean serum concentration of high-density lipoprotein was 41.4 ± 12.4 and 49.9 ± 26.2 mg/d l in patients with PCI and without PCI, respectively (p = 0.049). There was a trend towards increased prevalence of diabetes in patients with PCI (p = 0.057), and atrial fibrillation was tended to

be less frequent in these patients ($p = 0.080$); Serum concentration of Troponin I and Creatine Kinase MB Isoenzyme (CK-MB) tended to be higher in patients undergoing PCI ($p = 0.075$ & $p = 0.086$, respectively). There was no significant difference in other traditional cardiovascular risk factors, including family history, age, BMI, hypertension, history of smoking and low-density lipoprotein (LDL). Furthermore, there was no significant difference in the presence of angina pectoris ($p = 0.128$) or other symptoms.

3.1. CHA₂DS₂-VASC score of ICD-patients with VA

Patients were classified according to their CHA₂DS₂-VASC score. Forty-nine patients (27%) had a low score of 1–3, ninety-nine patients (54%) presented with an intermediate score of 4–5, and thirty-five patients (19%) had a high score of 6–8. There was no patient with a score of 0 or 9. Baseline characteristics according to CHA₂DS₂-VASC score are shown in Table 1. CHA₂DS₂-VASC score was higher in patients who underwent PCI ($p = 0.002$). In total, median CHA₂DS₂-VASC score was 5 [3–5]. Corresponding to the score parameters, patients with a higher score were older, more often female and had more comorbidities, such as vascular disease and diabetes mellitus (Table 1). 25.7% of patients in the high score group had a prior stroke event, compared with 3% and 0% in the intermediate and low score group ($p < 0.001$). Patients with prior ischemic cardiomyopathy and patients with a previous coronary artery bypass graft (CABG) had a higher score ($p = 0.003$ & $p = 0.018$, respectively). A higher score was associated with an increased serum creatinine ($p < 0.001$), and the presence of symptoms ($p = 0.036$). Notably, patients in the high score group had lower values of LDL, cholesterol, triglycerides and hemoglobin (Table 1). There was no significant difference in LVEF ($p = 0.160$), values of Troponin I ($p = 0.101$) and CK-MB ($p = 0.270$).

3.2. CHA₂DS₂-VASC score as predictor of CAD leading to PCI

PCI was performed in 13.3%, 38.4% and 40.0% of patients with a low, intermediate and high CHA₂DS₂-VASC score ($p = 0.016$). Using a logistic regression multivariate analysis when adjusting for risk factors, which included ischemic cardiomyopathy, history of smoking, LDL, LVEF, angina pectoris, renal function, NYHA class and indication of ICD, CHA₂DS₂-VASC score remained as only significant predictor for CAD progression leading to PCI after VA (Table 2). One increase in the CHA₂DS₂-VASC score was associated with a 1.73-fold (1.07–2.80) increase in the risk of CAD leading to PCI ($p = 0.025$). The Area under curve (AUC) for the ability of CHA₂DS₂-VASC score to predict coronary artery occlusion was 0.638 (95% CI 0.557–720, $p = 0.002$). In comparison to the presence of angina pectoris, ischemic cardiomyopathy and troponin I levels, the CHA₂DS₂-VASC score had a significant and higher AUC (Table 3).

3.3. CHA₂DS₂-VASC score as predictor of mortality after VA

During 3-year follow-up after coronary angiography mortality occurred in 7%, 20.9% and 36.7% patients with low, intermediate and high CHA₂DS₂-VASC score. Kaplan-Meier curves and the log-rank test revealed that patients with an intermediate or high CHA₂DS₂-VASC score had significantly higher incidence of death in comparison to individuals with a low score ($p = 0.003$) (Fig. 1). In Cox regression multivariable analysis when adjusting for risk factors which included age, body mass index, history of smoking, chronic obstructive pulmonary disease, atrial fibrillation, serum creatinine, ischemic cardiomyopathy and LVEF, the CHA₂DS₂-VASC score remained a significant predictor for 3-year mortality (HR 2.20, 95% CI 1.17–4.14, $p = 0.014$) (Table 4). Serum creatinine was also a significant predictor of 3-year mortality (HR 1.38, 95% CI 1.01–1.89, $p = 0.044$). In univariate analysis, indication for ICD

implantation (primary vs secondary prevention) showed no significant association with 3-year mortality ($p = 0.515$).

4. Discussion

In this study, we investigate the utility of the CHA₂DS₂-VASC score as an independent predictor of CAD progression leading to PCI after detected VA in ICD-patients. The score could be helpful for the risk stratification, evaluating the use of an invasive coronary angiography after VA. We demonstrate that each 1-point rise in the CHA₂DS₂-VASC score is correlated with a 1.73-fold increase in the risk of CAD leading to a PCI in ICD-patients after VA. The correlation of this simple score with relevant CAD progression is a new finding. The CHA₂DS₂-VASC score also correlates significantly with all-cause mortality in these patients – both unadjusted and when adjusted for potential confounders.

VA after acute myocardial ischemia are relatively common [15]. Thus, in patients presenting with acute life-threatening arrhythmia an immediate invasive strategy is recommended [5,16]. Other traditional criteria for coronary angiography are acute heart failure, angina pectoris, electrocardiogram changes and elevated troponin or CK-MB levels. The decision-making for an invasive strategy is also influenced by intermediate-risk criteria such as recent PCI, prior CABG, renal insufficiency and diabetes mellitus [5]. The risk stratification for invasive coronary angiography can be difficult though, if the patient is protected with an ICD which is effective terminating VA [2]. Recurrent VA can be common in these patients and clinically non-apparent. Also, biomarkers such as troponin and CK-MB can be elevated due to ICD-shocks rather than myocardial ischemia [17,18] and therefore might be losing their ability to predict coronary artery stenosis. In this present study, ROC curve analysis revealed no significant ability for troponin or CK-MB to predict PCI after VA (Table 3). We believe that in ICD-patients there is a lack of tools to predict CAD progression and to evaluate invasive diagnostic procedures. In fact, only 32.8% of patients showed a relevant CAD and underwent PCI. Thus, in the majority of patients the risks and costs of coronary angiography could have been avoided. Comparing the differences between patients who underwent PCI and patients who did not undergo PCI, the known cardiovascular risk factors did not show significance, except the history of ischemic cardiomyopathy. Univariate analysis confirmed a predictive ability of ischemic cardiomyopathy which is known to be associated with VA [19]. Although, comparing ischemic cardiomyopathy to the CHA₂DS₂-VASC score, the CHA₂DS₂-VASC score had the upper hand in predicting PCI after VA (Table 3). Furthermore, multivariable analysis revealed the CHA₂DS₂-VASC score as only remaining predictor.

AF was tended to be less frequent in patients who underwent PCI ($p = 0.080$). Previous studies have shown that in heart failure patients with high CHA₂DS₂-VASC score mortality rates may be higher in patients without pre-existing AF than in those with pre-existing AF, which can be considered as consistent with our finding despite the different endpoint [11,20]. However, in these studies AF could have been underdiagnosed since it can be silent frequently. In our collective though, most patients had ICD interrogations regularly, which should have reduced the presence of silent AF. The majority of patients with pre-existing AF received oral anticoagulation which might have served protectively against progression of CAD [21].

Of note is that none of the 12 patients with a CHA₂DS₂-VASC score of less than three points underwent PCI. In further evaluation of the predictive value, ROC analysis revealed a rather moderate AUC which indicates a limitation in the predictive power. However, our aim was to evaluate the CHA₂DS₂-VASC score as a predictor to use complementary, rather than a diagnostic tool intended to

Table 1
Baseline characteristics according to the CHA₂DS₂-VASC score.

CHA ₂ DS ₂ -VASC score category	Low score 1–3n = 49 (27%)	Intermediate score 4–5 n = 99 (54%)	High score 6–8n = 35 (19%)	P value
Clinical characteristics				
Age, years (Mean)	59 ± 6.8	73 ± 8.2	81 ± 10.6	<0.001
BMI, kg/m ²	28.4 ± 5.7	27.8 ± 4.5	26.1 ± 3.9	0.136
Women, n (%)	3 (6.1%)	8 (8.1%)	10 (28.6%)	0.002
Diabetes	5 (10.2%)	29 (29.3%)	25 (71.4%)	<0.001
Hypertension	47 (95.9%)	99 (100%)	35 (100%)	0.063
Prior stroke	0	3 (3.0%)	9 (25.7%)	<0.001
Smoker	28 (57.1%)	43 (43.4%)	13 (37.1%)	0.148
COPD	3 (6.1%)	10 (10.1%)	6 (17.1%)	0.261
Vascular disease	30 (61.2%)	89 (89.9%)	34 (97.1%)	<0.001
Previous acute coronary syndrom	9 (18.4%)	32 (32.3%)	8 (22.9%)	0.166
Previous CABG	5 (10.2%)	31 (31.3%)	10 (28.6%)	0.018
Ischemic cardiomyopathy	28 (57.1%)	70 (70.7%)	32 (91.4%)	0.003
Atrial fibrillation	5 (10.2%)	19 (19.2%)	7 (20.0%)	0.338
ICD as secondary prevention	26 (53.1%)	66 (66.7%)	25 (71.4%)	0.158
LVEF, % (Median)	36 (27–53)	31 (24–43)	32 (24–42)	0.160
Laboratory assessment				
Serum creatinine, mg/dl	1.05 (0.86–1.46)	1.32 (1.10–1.69)	1.84 (1.20–2.50)	<0.001
Potassium, mmol/l	4.5 (4.1–4.8)	4.4 (4.2–4.8)	4.5 (4.1–4.8)	0.719
Troponin I, µg/l	0.04 (0.02–0.25)	0.06 (0.02–0.38)	0.21 (0.035–1.01)	0.101
CK, U/l	111 (95–183)	110 (67–174)	100 (69–159)	0.616
CK-MB, U/l	2.4 (1.13–3.48)	2.6 (1.70–4.38)	2.8 (1.60–5.10)	0.270
LDL, mg/dl	92 (85–115)	98 (76–118)	76 (62–96)	0.030
HDL, mg/dl	43 (37–52)	44 (37–54)	44 (36–48)	0.985
Cholesterol, mg/dl	168 ± 48	172 ± 40	140 ± 45	0.035
Triglycerides, mg/dl	148 (115–191)	150 (113–274)	109 (84–149)	0.043
TSH, µU/ml	1.38 (0.93–2.27)	1.22 (0.74–2.11)	1.59 (0.56–2.63)	0.863
Hemoglobine, mg/l	14.5 (13.3–15.1)	14.1 (12.7–14.7)	12.5 (10.8–13.7)	<0.001
Presenting symptoms				
Angina pectoris, n(%)	12 (24.5%)	46 (46.5%)	16 (45.7%)	0.029
Palpitation	2 (4.1%)	14 (14.1%)	4 (11.4%)	0.181
Dizziness	8 (16.3%)	17 (17.2%)	13 (37.1%)	0.029
Syncope	8 (16.3%)	9 (9.1%)	11 (31.4%)	0.007
NYHAIII/IV	9 (18.4%)	26 (26.3%)	14 (40.0%)	0.086
Asymptomatic	25 (51.0%)	33 (33.3%)	9 (25.7%)	0.036
Antiarrhythmic medication				
Beta-blocker	46 (93.9%)	92 (92.9%)	32 (94.1%)	0.960
Calcium channel blocker	6 (12.2%)	5 (5.1%)	1 (8.3%)	0.160
Amiodarone or flecainide	24 (49.0%)	42 (42.4%)	14 (41.2%)	0.704

Values are n (%), mean ± SD, or median with interquartile range (quartile 1 to quartile 3). Abb.: BMI = Body mass index; COPD = Chronic obstructive pulmonary disease; CABG = Coronary artery bypass graft; ICD = Implantable cardiac defibrillator; LVEF = Left ventricular ejection fraction; CK = Creatine kinase; CK-MB = Creatine Kinase MB Isoenzyme; LDL = Low-density lipoprotein; HDL = High-density lipoprotein; TSH = Thyroid-stimulating hormone; NYHA = New York Heart Association class.

Table 2
Predictors of percutaneous coronary intervention.

	Univariate Predictors		Multivariate Predictors	
	HR (95% CI)	P value	HR (95% CI)	P value
CHA ₂ DS ₂ -VASC (per unit increase)	1.81 (1.12–2.91)	0.015	1.73 (1.07–2.80)	0.025
Age (per 1 year increase)	1.02 (0.99–1.05)	0.150		
Female gender	2.0 (0.81–5.11)	0.129		
Diabetes	1.87 (0.98–3.57)	0.058		
Prior Stroke	0.39 (0.08–1.84)	0.234		
Congestive Heart Failure	3.56 (0.43–29.62)	0.240		
Smoker	0.95 (0.51–1.76)	0.864	1.57 (0.67–3.68)	0.295
Previous CABG	1.13 (0.56–2.28)	0.739		
Ischemic cardiomyopathy	3.16 (1.42–7.02)	0.005	1.59 (0.48–5.22)	0.441
ICD as secondary prevention	1.68 (0.86–3.27)	0.130	1.66 (0.58–4.71)	0.359
BMI (per 1 kg/m ² increase)	0.97 (0.90–1.04)	0.400		
LVEF (per 1% increase)	0.98 (0.96–1.01)	0.169	0.98 (0.94–1.01)	0.153
Creatinine (per 1 mg/dl increase)	0.84 (0.60–1.19)	0.338	0.55 (0.28–1.09)	0.087
Low-density lipoprotein (per 1 mg/dl increase)	1.00 (0.99–1.01)	0.847	1.00 (1.00–1.01)	0.393
Hemoglobin (per 1 mg/dl increase)	0.99 (0.85–1.15)	0.866		
Angina pectoris	1.62 (0.87–3.03)	0.130	1.34 (0.57–3.14)	0.507
NYHA III/IV	0.99 (0.49–1.99)	0.981	0.69 (0.25–1.90)	0.482
No symptoms	0.65 (0.34–1.25)	0.196		

The CHA₂DS₂-VASC score remained as only independent predictor of the primary endpoint after adjusting for risk factors. Abb.: BMI = Body mass index; CABG = Coronary artery bypass graft; ICD = Implantable cardiac defibrillator; LVEF = Left ventricular ejection fraction, NYHA = New York Heart Association.

Table 3
Receiver operating characteristic curve analysis.

	AUC	95% CI	p value
CHA ₂ DS ₂ -VASC	0.638	0.557–0.720	0.002
Troponin I	0.601	0.490–0.711	0.080
CK-MB	0.599	0.489–0.709	0.087
ICM	0.604	0.520–0.688	0.023

Significant and highest area under curve (AUC) was measured for the CHA₂DS₂-VASC score to predict coronary artery disease leading to reperfusion therapy. Abb.: CK-MB = Creatine Kinase MB Isoenzyme; ICM = Ischemic cardiomyopathy.

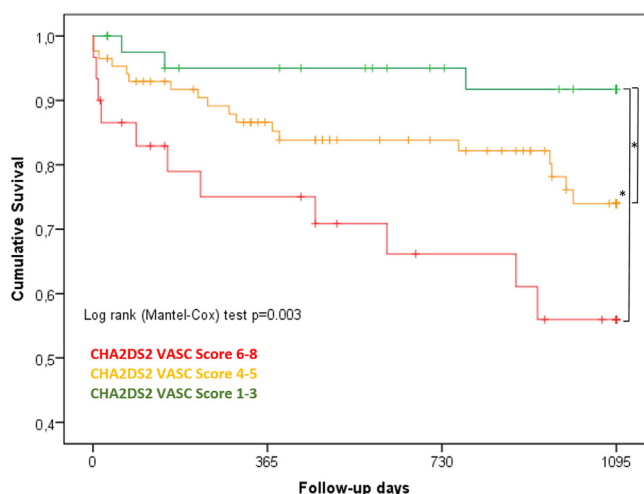


Fig. 1. Kaplan-Meier survival curves stratified by CHA₂DS₂-VASC score for 3-year mortality. Patients with a high score (6–8 points) and patients with an intermediate score (4–5 points) had lower survival than patients in the low score group (1–3 points). * indicates p-Value < 0.05.

Table 4
Multivariate predictors of mortality.

	Multivariate Predictors	
	HR (95% CI)	P value
CHA ₂ DS ₂ -VASC (per unit increase)	2.20 (1.17–4.14)	0.014
Age (per 1 year increase)	0.97 (0.90–1.04)	0.330
Smoker	1.49 (0.53–4.15)	0.451
COPD	1.54 (0.39–6.12)	0.540
Ischemic cardiomyopathy	0.52 (0.16–1.71)	0.524
BMI (per 1 kg/m ² increase)	0.95 (0.85–1.06)	0.950
LVEF (per 1% increase)	0.99 (0.95–1.03)	0.987
Creatinine (per 1 mg/dl increase)	1.38 (1.01–1.89)	0.044
Atrial fibrillation	2.02 (0.69–5.96)	0.277

The CHA₂DS₂-VASC score and serum creatinine were independent predictors of 3-year-mortality. Abb.: BMI = Body mass index; COPD = Chronic obstructive pulmonary disease; ICD = Implantable cardiac defibrillator; LVEF = Left ventricular ejection fraction.

replace other known predictors for relevant CAD. As an easy to implement score it may help to identify patients with VA who would benefit from invasive coronary angiography.

The CHA₂DS₂-VASC score is mostly known for its ability to predict the risk of stroke in patients with AF [6]. Beyond this initial use, recent studies have demonstrated its ability predicting death in patients with or without AF and in various cardiovascular conditions [8,9,11]. Studies have shown its prognostic value in patients with acute coronary syndrome [9,22,23]. In the study of Poçi et al., patients with a high score had a worse 10-year survival rate after acute coronary syndrome, irrespective of the presence or absence of AF. Consistent with these findings, in the present study, ICD-patients with an intermediate or high CHA₂DS₂-VASC score had a

worse clinical outcome with an elevated all-cause mortality during three-year follow-up after VA (Fig. 1). After adjusting for interactions between the score and known mortality risk factors such as age, chronic obstructive pulmonary disease, body mass index, LVEF, creatinine, AF etc. it remained an independent predictor of mortality (Table 4). Thus, the CHA₂DS₂-VASC score might serve as a simple tool for risk stratification in patients after VA, irrespective of the presence or absence of AF. The other remaining independent predictor of all-cause mortality after VA was creatinine, which is concordant to recently published data [24]. In 83% of patients, VA (of which 39% were ventricular fibrillation) led to antitachycardia pacing and/or shock by the ICD. Although speculative, mortality rates presumably would have been much higher in this cohort without the pre-existing ICD.

4.1. Study limitation

Limitations of our study are its monocentric and retrospective character. Furthermore, indication for invasive coronary treatment strategy could have differed as it was evaluated by individual cardiologists. However, revascularization therapies were in line with the European guidelines, though [14]. Moreover, evaluation of relevant coronary stenosis was made primarily by visual inspection. However, this procedure represents the clinical all-day scenario.

5. Conclusion

The CHA₂DS₂-VASC score can be used to optimize the risk stratification, evaluating invasive coronary angiography after VA in ICD-patients. Moreover, the CHA₂DS₂-VASC score predicts a reduced survival rate in ICD-patients who experienced VA. Patients with a high score may require more intense monitoring due to a higher risk for all-cause mortality.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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