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Clinical predictors of appropriate electrical storm in patients with implantable cardioverter defibrillator

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SOUHRN

Kontext: Skutečná elektrická bouře (electrical storm, ES) u pacientů s implantabilním kardioverterem-defibrilátorem (implantable cardioverter-defibrillator, ICD) je život ohrožující stav s opakovanými výboji ICD a vyžadující antitachykardickou stimulaci (antitachycardia pacing, ATP) a/nebo výboje v období 24 hodin. Někteří autoři definují ES jako tři nebo více epizod komorové tachykardie nebo fibrilace komor oddělených sinusovým rytmem v délce alespoň 5 minut. Výboje ICD mají významné nepříznivé účinky a dostupné důkazy ukazují, že pacienti, u nichž k ES dojde, mají horší výsledný stav. Mezi potenciální spouštěče patří změny v medikaci nebo nedodržování léčebného režimu (non-adherence), zhoršující se srdeční selhání, časné pooperační stavy, citové vypětí, nadměrná konzumace alkoholu, rozvrat iontové rovnováhy, ischemie myokardu a méně časté faktory jako horečka. K mnoha epizodám ES však dochází bez jakékoli vysvětlitelné příčiny.
Cíle studie: Cílem této studie bylo zhodnotit klinické prediktory skutečné elektrické bouře u pacientů s ICD.
Pacienti a metody: Tato monocentrická, retrospektivní, observační studie případů a kontrol se prováděla na specializovaném kardiochirurgickém pracovišti Ibn Al-Bitar Specialist Center for Cardiac Surgery v iráckém Bagdádu v období od 1. dubna 2016 do 1. ledna 2017. Do skupiny případů bylo zařazeno 25 po sobě následujících pacientů s ICD, přijatých pro skutečnou ES; ti byli srovnáváni s 25 s implantovanými ICD, avšak bez ES, kteří na uvedené pracoviště docházeli pro rutinní programování přístroje a sledování.
Výsledky: Byly analyzovány údaje celkem 50 pacientů s ICD: 25 s ES (případy) a 25 bez ES (kontroly). Průměrný věk ve skupinách případů a kontrol byl 54 ± 12,09 roku, resp. 54,8 ± 12,19 roku. Mužů bylo ve skupině případů 84 % a v kontrolní skupině 40 %. Hypertenze byla zjištěna u 56 % případů a 36 % kontrol; diabetes byl přítomen u 36 % pacientů v obou skupinách. Ischemická choroba srdeční se vyskytovala častěji u případů (80 %) než u kontrol (44 %). Ejekční frakce levé komory (EF LK) < 40 % byla naměřena u 80 % případů a u 44 % kontrol. K nedávné dekompenzaci srdečního selhání (v posledním měsíci) došlo u 56 % případů a pouze u 8 % kontrol.
Pokud se týče indikace k implantaci ICD, v 80 % případů a u 84 % kontrol se jednalo o sekundární prevenci. Přístroje ICD-VR byly použity častěji u případů (84 %) než u kontrol (44 %), zatímco přístroje ICD-DR byly méně často použity u případů (16 %) než u kontrol (56 %). Systolické srdeční selhání byl přítomno u 80 % pacientů v obou skupinách. Mezi další etiologie patřily HOCM (2 případy/2 kontroly), syndrom krátkého intervalu QT (2 případy/2 kontroly) a syndrom Noonanové (1 případ/1 kontrola). Obezita (BMI >30) byla častější u případů (68 %) než u kontrol (16 %).
Horečka, teplota > 38 °C, v době ES byla doložena u 28 % případů oproti 0 % u kontrol. Kuřáctví bylo častější u případů (56 %) než u kontrol (40 %). Vysoká konzumace alkoholu byla popsána u 4 % případů i kontrol. Všichni účastníci studie měli normální funkci štítné žlázy. Hypokalemie (< 3,5 mmol/l) byla zjištěna u 64 % případů a 24 % kontrol a nízké hodnoty hořčíku (< 1,6 mg/dl) byly nalezeny u 64 % případů a 24 % kontrol. Ani v jedné z hodnocených skupin nebyly provedeny časné kardiální nebo nekardiální výkony.
Závěr: Elektrická bouře představuje poměrně častou komplikaci, k níž může dojít kdykoli po implantaci ICD a může se opakovat. Studie zjistila několik prediktorů ES včetně snížené EF LK, implantace ICD v rámci sekundární prevence, rozvratu iontové rovnováhy a nepodávání amiodaronu či inhibitorů ACE.

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ABSTRACT

Background: Appropriate electrical storm (ES) in patients with implantable cardioverter-defibrillators (ICDs) is a life-threatening condition characterized by recurrent, appropriate ICD therapies; antitachycardia pacing (ATP) and/or shocks; within a 24-hour period. Some authors define ES as three or more VT/VF episodes separated by at least 5 minutes of sinus rhythm. ICD shocks have significant adverse effects, and available evidence indicates that patients experiencing ES have poorer outcomes. Potential triggers include changes in or non-adherence to medication, worsening heart failure, early postoperative states, emotional stress, alcohol excess, electrolyte imbalances, myocardial ischemia, and less common factors such as fever. However, many ES episodes occur without any identifiable cause.

Objectives: This study aimed to evaluate clinical predictors of appropriate electrical storm in patients with ICDs.

Patients and methods: This single-center, retrospective, observational case-control study was conducted at Ibn-Albitar Specialist Center for Cardiac Surgery from April 1, 2016 to January 1, 2017. Twenty-five consecutive ICD patients admitted with appropriate electrical storm were included as the case group and compared with 25 ICD recipients without ES who attended the center for routine programming and follow-up.

Results: A total of 50 ICD patients were analyzed: 25 with ES (cases) and 25 without ES (controls). The mean ages of the case and control groups were 54 ± 12.09 years and 54.8 ± 12.19 years, respectively. Males constituted 84% of the case group and 40% of the control group. Hypertension was present in 56% of cases and 36% of controls, and diabetes was present in 36% of both groups. Ischemic heart disease was more prevalent among cases (80%) than controls (44%). Left ventricular ejection fraction (LVEF) <40% was found in 80% of cases compared with 44% of controls. Recent heart failure decompensation (within 1 month) occurred in 56% of cases and only 8% of controls.

Regarding ICD indication, secondary prevention accounted for 80% of cases and 84% of controls. ICD-VR devices were more common in cases (84%) than in controls (44%), while ICD-DR devices were less frequent in cases (16%) versus controls (56%). Systolic heart failure was present in 80% of both groups. Other etiologies included HOCM (2 cases/2 controls), short QT syndrome (2 cases/2 controls), and Noonan syndrome (1 case/1 control). Obesity (BMI >30) was more prevalent in cases (68%) than in controls (16%).

Fever >38 °C at the time of ES was documented in 28% of cases, with none reported in controls. Current smoking was more common among cases (56%) than controls (40%). Heavy alcohol use occurred in 4% of both groups. Thyroid function was normal across all subjects. Hypokalemia (<3.5 mmol/L) was present in 64% of cases and 24% of controls, while low magnesium (<1.6 mg/dL) was found in 64% of cases versus 24% of controls. No early cardiac or non-cardiac surgical interventions had occurred within 6 months in either group.

Conclusion: Electrical storm is a relatively common complication that may occur at any point after ICD implantation and may recur. The study identified several predictors of ES, including reduced LVEF, ICD implantation for secondary prevention, electrolyte disturbances, and absence of amiodarone or ACE-inhibitor therapy.

Introduction

An implantable cardioverter-defibrillator (ICD) storm may result from appropriate therapy (antitachycardia pacing, cardioversion, or defibrillation), inappropriate therapy (shocks delivered without a true arrhythmia), or phantom shocks. The latter two conditions are not considered true electrical storms. Patients who report receiving a shock but whose device interrogation shows no delivered therapy require appropriate reassurance.[1]

Potential triggers of appropriate electrical storm (ES) include alterations in or non-compliance with medication regimens, worsening heart failure, the early postoperative period, emotional stress or anger, excessive alcohol intake, electrolyte disturbances, myocardial ischemia, and less common causes such as fever or physical stress. Nonetheless, the majority of ES episodes occur without an identifiable precipitating factor.[2]

Clinical presentation varies widely depending on arrhythmia type; monomorphic VT, polymorphic VT, or ventricular fibrillation (VF); as well as patient-specific factors such as left ventricular ejection fraction (LVEF), NYHA class, and comorbidities. The occurrence of syncope is influenced by both hemodynamic status and ICD programming parameters, particularly shock charging time. Patients who experience an initial ES episode are at increased risk for recurrence, with recurrence rates reported as high as 80% within 12 months. Steinert identified LVEF <30%, age >65 years, chronic obstructive pulmonary disease, and absence of ACE inhibitor therapy as independent predictors of ES recurrence.[3]

Despite growing global evidence regarding risk factors and outcomes associated with electrical storm, data from the Middle East remain scarce. Regional studies addressing clinical predictors, precipitating factors, and device-related characteristics are particularly limited, despite a rising burden of ischemic heart disease, heart failure, and ICD implantation in Middle Eastern populations. This gap restricts the ability to apply region-specific, evidence-based management strategies and highlights the need for locally derived clinical data.

Therefore, the aim of this study was to evaluate the clinical predictors of appropriate electrical storm in patients with implantable cardioverter-defibrillators.

Patients and methods

This single-center, retrospective, observational case-control study was conducted at Ibn Al-Bitar Specialist Center

for Cardiac Surgery between April 1, 2016, and January 1, 2017. The study enrolled 25 consecutive ICD patients admitted to the coronary care unit with a diagnosis of appropriate electrical storm (case group) and compared them with an additional 25 ICD recipients without ES who attended the center for device programming and follow-up (control group).

During each device interrogation, we evaluated the number and type of arrhythmia-related events (sustained and non-sustained VT), the number of antitachycardia pacing (ATP) therapies delivered, and the number and appropriateness of shocks. Control group classification was based on patient history, outpatient ICD interrogation, and review of medical records.

A detailed patient history was obtained on admission, including: name, age, sex, address, diabetes, hypertension, ischemic heart disease or other structural heart disease, recent decompensated heart failure (within one month), LVEF, thyroid disease, obesity, fever, recent surgery, medication use and compliance (including amiodarone and other antiarrhythmics, β-blockers, diuretics), smoking status, alcohol consumption, time since ICD implantation, indication for implantation (primary or secondary prevention), ICD type (single- or dual-chamber), manufacturer, indication classification, and type of documented arrhythmias.

Exclusion criteria: Patients with inappropriate shocks or phantom shocks were excluded based on device programming data.

Definitions

- Acute decompensated heart failure: An acute or subacute worsening of heart failure, usually due to identifiable precipitants, typically presenting with systemic and pulmonary congestion or requiring hospitalization for pulmonary edema.
- Coronary heart disease: Defined as self-reported myocardial infarction, history of revascularization, or ECG evidence of previous infarction.
- Diabetes: Defined as serum glucose ≥126 mg/dL after ≥8 hours of fasting, serum glucose ≥200 mg/dL in non-fasting patients, or self-reported physician diagnosis with concurrent use of insulin or oral hypoglycemic agents.
- Hypertension: Systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, or current use of antihypertensive medications.
- Body mass index (BMI): Calculated as weight (kg) divided by height (m^2).
- Heavy alcohol consumption: Defined as >14 drinks per week for men and >7 drinks per week for women.

Laboratory investigations included serum electrolytes (K^+, Mg^{2+}, Ca^{2+}, Na^+), thyroid function tests, and blood glucose. All analyses were performed in the hospital's central laboratory.

Statistical analysis

Data were processed and analyzed using SPSS version 23. Categorical variables were presented as numbers and percentages and were analyzed using the chi-square test. Risk estimation was performed using odds ratios. A *p*-value <0.05 was considered statistically significant.

Results

A total of 25 patients with ICD-related electrical storm were included as the case group, and 25 ICD patients without electrical storm were enrolled as the control group.

Based on data from **Tables 1** and **2**:

Table 1 – Characteristics of patients who present with ICD electrical storm

Patients' characteristics	Number and percentage of cases
Age (year)	37–79 year
Gender Males Females	 21 (84%) 4 (16%)
Hypertension	14 (56%)
Diabetes	9 (36%)
IHD	20 (80%)
Type of ICD implant indication	20 (80%) secondary 5 (20%) primary
ICD type DR VR	 4 21
ICD manufacturer	11 Medtronic 9 Biotronic 3 St. Jude Medical, 2 Boston Scientific
Acute decompensated heart failure No recent decompensation	14 (56%) 11 (44%)
BMI More than or equal 30 Less than 30	 17 (68%) 8 (32%)
Thyroid function test	100% normal
Alcoholic	1 (4%)
Smoking status Smoker Non-smoker	 14 (56%) 11 (44%)
Serum potassium Hypokalemia Normal	 16 (64%) 9 (36%)
Serum magnesium Low Normal	 16 (64%) 9 (36%)
Serum sodium Low Normal	 4 (16%) 21 (84%)
Serum calcium Low Normal	 3 (12%) 22 (88%)
QT interval (ecg) Normal Short	 23 (92%) 2 (12%)
Serum creatinine > 130 < 130	 5 (20%) 20 (80%)

Continued

Table 1 – Characteristics of patients who present with ICD electrical storm

Patients' characteristics	Number and percentage of cases
Structural cardiac disease	
Systolic heart failure	20 (80%)
HOCM	2 (4%)
Short QT	2 (4%)
Noonan syndrome	1 (8%)
Concomitant medications	
Beta-blocker	19 (76%)
Amiodarone	3 (12%)
ACEI/ARBs	12 (48%)
Spironolactone	12 (48%)
Digoxin	6 (24%)
Loop diuretics	19 (76%)
Statins	14 (56%)
Fever (≥38 °C)	7 (28%)

The mean age of the cases was 54 ± 12.09 years (range 37–79), compared with 54.8 ± 12.19 years (range 33–86) in the control group. Males constituted 84% (n = 21) of the cases and 40% (n = 10) of the controls, while females accounted for 16% (n = 4) of cases and 60% (n = 15) of controls.

Hypertension was present in 56% of cases and 36% of controls, while diabetes was observed in 36% of both groups. Ischemic heart disease (IHD) was significantly more frequent among cases (80%) than controls (44%). Patients with IHD were 12.6 times more likely to experience electrical storm compared with ICD patients without ES ($p = 0.02$).

Left ventricular ejection fraction (LVEF) <40% was found in 80% of cases and 44% of controls, demonstrating a significant association ($p = 0.02$). Thus, patients with reduced LVEF were more susceptible to electrical storm than those with LVEF ≥40%.

Table 2 – The clinical characteristics of patients with electrical storm, compared with patients without electrical storm (control)

Risk factors	ICD patients		*p*-value	Odds ratio
	ES	No ES		
Age				
Range	37–79	33–86		
Mean	(55)	(54.8)		
STD	12.09	12.19		
Gender				
Male	21 (84%)	10 (40%)	0.04	7.875
Female	4 (16%)	15 (60%)		
Diabetes				
DM+	9 (36%)	9 (36%)	1	1
DM–	16 (64%)	16 (64%)		
Hypertension	14 (56%)	9 (36%)		
	11 (44%)	16 (64%)	0.25	2.263
IHD				
IHD+	20 (80%)	11 (44%)	0.020	12.66
IHD–	5 (20%)	14 (56%)		
LVEF (%)				
<40%	20 (80%)	11 (44%)	0.02	5
≥40%	5 (20%)	14 (56%)		
Acute or chronic decompensated HF				
Decompensated	14 (56%)	2 (4%)	0.01	14.6
Compensated	11 (44%)	23 (92%)		
Thyroid function tests				
Normal level	25	25	–	–
BMI				
≥30	17 (68%)	4 (16%)	0.001	11.15
<30	8 (32%)	21 (84%)		
Type of prevention				
Primary	5 (20%)	4 (16%)		
Secondary	20 (80%)	21(84%)	1	1.313
ICD type				
DR	4 (16%)	14 (65%)	0.008	0.15
VR	21 (84%)	11 (44%)		
Type of ICD manufactory				
Medtronic	11	9		
Biotronic	9	9	0.90	–
St. Jude Medical	3	4		
Boston	2	3		

Continued

Table 2 – The clinical characteristics of patients with electrical storm, compared with patients without electrical storm (control)

Risk factors	ICD patients		*p*-value	Odds ratio
	ES	No ES		
Fever			0.04	2.38
≥38 °C	7 (28%)	0		
Normal temperature	18 (72%)	25 (100%)		
Structural cardiac diseases				
Systolic HF	21	21		
HOCM	2	2		
Short QT	1	1		
Noonan syndrome	1	1		
Beta-blockers				
Use	19 (76%)	22 (88%)	0.4	0.4
Not use	6 (24%)	3 (12%)		
Amiodarone				
Use	3 (12%)	14 (56%)	0.003	0.107
Not use	22 (88%)	11(44%)		
ACEI				
Use	12 (48%)	19 (76%)	0.08	0.29
Not use	13 (52%)	6 (24%)		
Statins				
Use	14 (56%)	15 (60%)	0.5	–
Not use	11 (44%)	10 (40%)		
Spironolactone				
Use	12 (48%)	18 (72%)	0.1	0.3
Not use	13 (52%)	7 (28%)		
Loop diuretic				
Use	19 (76%)	19 (76%)	1	1
Not use	6	6		
Digoxin				
Use	6 (24%)	8 (32%)	0.7	0.6
Not use	19 (76%)	17 (68%)		
Heavy alcohol				
Use	1 (4%)	1 (4%)	1	1
Not use	24	24		
Smoking				
Current	14 (56%)	10 (40%)	0.3	2
Non-smoker	11 (44%)	15 (60%)		
K+				
Normal	9 (36%)	19 (76%)	0.01	2
Low	16 (64%)	6 (24%)		
Mg++				
Normal	9 (36%)	19 (76%)	0.01	0.17
Low	16 (64%)	6 (24%)		
Na+				
Normal	21 (84%)	25(100%)	0.11	–
Low	4 (16%)	0		
Ca++				
Normal	22 (88%)	22 (88%)	0.5	–
Low	3 (12%)	3 (12%)		
ECG – QTc INTERVAL				
Short	2	2		–
Normal	23	23		

Recent decompensated heart failure (within the preceding month) was present in 56% of cases and only 8% of controls. These patients were 14.6 times more likely to develop ES, representing a significant association ($p = 0.01$).

Regarding ICD indication, 80% of cases and 84% of controls had devices implanted for secondary prevention.

ICD-VR devices were identified in 84% (n = 21) of cases and 44% (n = 11) of controls, whereas ICD-DR devices were present in 16% (n = 4) of cases and 56% (n = 14) of controls. This demonstrated a statistically significant association between ICD-VR use and increased risk of ES ($p = 0.008$).

Among cases, 80% had systolic heart failure and 80% had IHD. Additionally, 2 patients had hypertrophic obstructive cardiomyopathy (HOCM), 2 had short QT syndrome, and 1 had Noonan syndrome. The control group included 80% with systolic heart failure, 44% with IHD, 2 with HOCM, 2 with short QT syndrome, and 1 with Noonan syndrome.

Obesity (BMI ≥30) was present in 68% of cases compared with 16% of controls, a significant association ($p = 0.001$). Obese patients were 11.15 times more likely to develop electrical storm than non-obese patients.

Fever >38 °C at the time of ES was documented in 28% of cases, while none of the controls reported fever in the preceding month. This association was statistically significant ($p = 0.04$).

Current smoking was reported in 56% of cases and 40% of controls. Smokers had approximately twice the risk of ES (OR = 2), although this was not statistically significant ($p = 0.3$).

Alcohol consumption was reported by 4% of both groups. There was no difference in risk between alcoholic and non-alcoholic patients (OR = 1; $p = 1$), indicating no significant association.

Thyroid function tests were normal in all participants, demonstrating no relationship between thyroid dysfunction and electrical storm.

Hypokalemia (serum K^+ <3.5 mmol/L) occurred in 64% of cases versus 24% of controls. This indicated that patients with low potassium levels had twice the estimated risk of ES compared with those with normal levels, with a significant association ($p = 0.007$).

Hypomagnesemia (serum Mg^{2+} <1.6 mg/dL) was observed in 64% of cases and 24% of controls. Patients with low magnesium levels also had approximately double the estimated risk of ES, a statistically significant association ($p = 0.01$).

All patients reported good medication adherence. Amiodarone use was recorded in only 12% (n = 3) of cases and 56% (n = 14) of controls. The odds ratio was 0.1, indicating a protective effect of amiodarone against electrical storm, with a significant association ($p = 0.003$).

β-blocker therapy was used by 76% of cases and 88% of controls; this association was not statistically significant ($p = 0.4$).

ACE inhibitor therapy was used by 48% of cases and 76% of controls; this association reached statistical significance ($p = 0.08$), suggesting a protective effect of ACE inhibitors against electrical storm in ICD patients.

Finally, none of the patients in either group had undergone recent cardiac or non-cardiac surgery within the previous 6 months.

Discussion

Electrical storm (ES), defined as three or more episodes of ventricular tachycardia (VT) or ventricular fibrillation (VF) within 24 hours, remains a serious complication in ICD recipients. In the present study, ES occurred predominantly among men, a finding that is consistent with the work of Lampert et al., who reported significantly higher rates of sustained VT/VF, shock-treated episodes, and electrical storms in male patients.[4] These gender-related differences were independent of clinical and electrophysiologic characteristics and were most evident in patients presenting with monomorphic VT or inducible VT during electrophysiological evaluation.[5]

Our findings indicate that ischemic heart disease (IHD) was strongly associated with ES, being present in 80% of affected patients. This contrasts with the study by Pil Sang Song et al., who identified non-ischemic dilated cardiomyopathy as an independent predictor of ES.[6] The high prevalence of IHD in our population may reflect regional disease patterns and underscores the arrhythmogenic vulnerability of patients with ischemic substrates.

Left ventricular systolic dysfunction also demonstrated a strong relationship with ES. In our study, 80% of patients with ES had an LVEF less than 40%, similar to the findings of Brigadeau et al., who showed that individuals with significant systolic dysfunction are more likely to experience electrical storm. Diabetes did not appear to play a significant role in ES development in our cohort, a result aligning with Brigadeau's assertion that diabetics may be less predisposed to ES episodes.[7]

Acute decompensated heart failure was identified as a major precipitating factor, affecting 65% of patients with ES. Streitner also emphasized the importance of worsening heart failure as a significant trigger and predictor of recurrent episodes of ES.[8] Another notable finding in our study was the high prevalence of obesity among ES patients. Although this association was statistically significant, comparative studies examining obesity as a risk factor for ES remain limited, making our observation potentially valuable for future research.

Infectious triggers, particularly fever, were evident in over a quarter of ES cases, consistent with guideline-based observations that infection and elevated body temperature predispose patients to ventricular arrhythmias.[9] Electrolyte imbalances were prominent as well, with hypokalemia and hypomagnesemia each present in 64% of ES cases, confirming their established role as arrhythmogenic triggers.[10]

Pharmacologic patterns revealed important associations. Amiodarone use was significantly lower in the ES group, reinforcing its protective effect against recurrent ventricular arrhythmias. This observation is supported by Greene, who demonstrated fewer ICD shocks and reduced arrhythmic syncope among patients receiving amiodarone.[11] By contrast, β-blocker use did not demonstrate a significant protective association in our cohort, although large studies such as MADIT-II have shown substantial reductions in arrhythmic events with high-dose β-blocker therapy.[4] The smaller sample size of our study may partially explain the discrepancy. ACE inhibitor therapy appeared to reduce the risk of ES, which aligns with Streitner et al., who identified the absence of ACE inhibitor therapy as a predictor of ES.[9]

Secondary-prevention ICD implantation was highly prevalent among ES cases in this study, mirroring earlier reports such as the AVID trial, which documented higher incidence of ES among patients with prior arrhythmic events or cardiac arrest compared with those receiving ICDs for primary prevention.[10,11] This highlights the ongoing risk faced by patients with significant arrhythmogenic histories.

The findings of this study also carry important clinical implications. Effective ES management should begin with prompt identification and correction of reversible precipitants such as myocardial ischemia, electrolyte abnormalities, fever, and acute decompensated heart failure. Pharmacologic therapy remains essential, with amiodarone and ACE inhibitors forming the cornerstone of treatment for many patients given their protective effects. Following stabilization of the acute episode, long-term care should focus on optimizing heart-failure therapy and reducing the likelihood of recurrent ventricular arrhythmias, particularly in individuals with low LVEF, IHD, or prior episodes of decompensation.

While the study provides important insights, several limitations should be acknowledged. The relatively small sample size reduces the statistical power of subgroup comparisons and may limit the generalizability of certain findings. The single-center design further restricts broader application of the results, and the retrospective nature introduces the possibility of incomplete or inconsistent documentation. Limited information on medication dosage, particularly for β-blockers, may also have influenced outcome interpretation. Nonetheless, a notable strength of this study is its relevance to an underrepresented Middle Eastern population, addressing a significant gap in regional data regarding ES predictors and their clinical implications. The systematic evaluation of clinical, laboratory, and device-related factors also strengthens the reliability of our observations.

Conclusions

Electrical storm represents a serious and potentially recurrent complication in patients with implantable cardioverter-defibrillators. In this study, several clinical characteristics were strongly associated with the development of ES, including reduced left ventricular ejection fraction, ischemic heart disease, recent decompensated heart failure, obesity, fever, and electrolyte disturbances; particularly hypokalemia and hypomagnesemia. Pharmacologic factors also played an important role, with the absence of amiodarone and ACE inhibitor therapy significantly increasing the likelihood of ES, while β-blocker therapy did not demonstrate a protective effect in this cohort. ES occurred more frequently among male patients and in those who received ICDs for secondary prevention, consistent with previous reports.

These findings underscore the importance of early identification and correction of modifiable triggers, particularly electrolyte abnormalities and acute heart-failure exacerbations, as well as the optimization of long-term medical therapy to reduce arrhythmia burden. The results further highlight the need for heightened vigilance among high-risk subgroups, especially those with ischemic cardiomyopathy and reduced LVEF.

Given the scarcity of regional data, this study contributes valuable insights into the characteristics and predictors of ES in a Middle Eastern population. Larger, multicenter studies are warranted to validate these findings and to support the development of region-specific risk-stratification and management strategies.

Conflict of interest
None.

Funding
None.

Ethical statement
This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Scientific and Ethics committee of the Arab Board of Health Specialisations.

Informed consent
Written informed consent was obtained from all individual participants included in the study prior to any data collection. All participants were informed of the study's purpose, the voluntary nature of their participation, and their right to withdraw at any time without affecting their clinical care.

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