Outcomes for patients with implanted cardioverter--defibrillators admitted to the Emergency Department due to electrical shock during the pre-pandemic and COVID-19 era

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Editorial
by Adabag et al.

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DOI: 10.33963/v.kp.98604

Received:
July 19, 2023

Accepted:
December 19, 2023

Early publication date:
December 29, 2023

ABSTRACT

Background: Implantable cardioverter-defibrillators (ICD)/cardiac resynchronization therapy with defibrillation (CRT-D) recipients may be susceptible to the arrhythmic effects of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection.

Aims: We aimed to evaluate characteristics and outcomes of patients hospitalized for ICD/CRT-D shocks during the pandemic compared to the pre-pandemic period.

Methods: This retrospective study analyzed medical records of patients hospitalized for ICD/CRT-D shock in the pre-pandemic (January 1, 2018–December 31, 2019) and pandemic periods (March 4, 2020–March 3, 2022). Survival data were obtained on October 24, 2022.

Results: In total, 198 patients (average age 65.6 years) had 138 pre-pandemic and 124 pandemic visits. Of these patients, 115 were hospitalized during pre-pandemic, 108 during the pandemic, and 25 in both periods. No significant differences were noted in age, sex, number of shocks, or appropriateness of therapy between these periods. During the pandemic, during 14 hospital stays of patients with SARS-CoV-2, 8 (57.1%) received electrical shocks, compared to 12 (10.9%) with negative SARS-CoV-2 tests (P <0.001). The in-hospital mortality rate was 2 of 115 patients hospitalized during the pre-pandemic and 7 of 108 during pandemic periods (4 patients with and 3 without SARS-CoV-2 [P = 0.10]). During the follow-up, there were 66 deaths. Cox regression analysis showed that survival decreased with age and heart failure decompensation in medical history but increased with higher ejection fraction. The pandemic alone was not a survival predictor. However, SARS-CoV-2 infection, older age, and heart failure decompensation in medical history predicted worse outcomes during the pandemic period.

Conclusions: The pandemic did not increase the number of hospital visits due to ICD/CRT-D discharges. SARS-CoV-2 infection predicts increased mortality in patients with ICD/CRT-D shocks.

Key words: cardiac resynchronization therapy, COVID-19, hospitalization, implantable cardioverter defibrillator, pandemic

INTRODUCTION

Coronavirus disease 19 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first cases were recognized in December 2019 in Wuhan, China [1]. In Poland, the first case of COVID-19 disease was documented on March 4, 2020 [2]. Since then, the number of infected patients increased rapidly [3, 4]. The symptoms of respiratory damage predomi-

WHAT'S NEW?

The global COVID-19 pandemic has profoundly affected healthcare systems, necessitating significant changes in patient care worldwide. Patients with implantable cardioverter-defibrillators or cardiac resynchronization therapy with defibrillation, who require meticulous monitoring and specialized attention, are particularly vulnerable. This study investigated the impact of the pandemic on hospitalization admissions in this patient cohort and showed that despite the pandemic, hospitalization rates remained unaffected. However, patients with concurrent SARS-CoV-2 infection experienced elevated rates of in-hospital shock incidents and mortality. These findings advance our understanding of the pandemic's influence on specific patient populations and offer valuable insights for future healthcare planning and resource allocation during comparable crises.

nate, but signs of cardiovascular involvement are frequent [5, 7]. Direct cardiac injury, autonomic dysfunction, stress myocardiopathy, vascular thrombosis, electrolyte disturbances, and release of proinflammatory cytokines are often encountered in patients with SARS-CoV-2 infection. Increased metabolic demand, combined with the above-mentioned factors, could evoke cardiac arrhythmias, which are usual extrapulmonary manifestations of the disease [7]. Patients with chronic conditions are particularly vulnerable to a severe disease course and increased risk of death [8, 9]. Many of them have an implanted cardioverter-defibrillator (ICD) or a cardiac resynchronization therapy defibrillator (CRT-D), and COVID-19 caused in these patients appropriate shocks triggered by ventricular arrhythmias and inappropriate shocks triggered by atrial fibrillation (AF) with a rapid ventricular response [10–12]. Furthermore, sinus tachycardia, often encountered in COVID-19, could be responsible for that inappropriate shock triggering [13]. However, a lower percentage of lethal ventricular arrhythmias in the general population during the pandemic era compared to the pre-pandemic period was indicated by a decrease in the percentage of shockable first recorded rhythm in patients with cardiac arrest [7]. The results of analyses on ICD shocks during the pandemic are contrasting [14, 15]. The electrical shock occurrence in ICD/CRT-D recipients could be increased by overall psychological stress [16, 17]. In contrast with these assumptions, lockdowns and decreased physical activity reduce the occurrence of shocks [10–12].

This retrospective study aimed to evaluate Emergency Department (ED) admissions related to high-energy therapy, examining patients' clinical characteristics and outcomes during both the pre-pandemic and COVID-19 pandemic periods. Secondary aims included assessing the incidence of SARS-CoV-2 infections in these patients and comparing the clinical data and outcomes between those with and without SARS-CoV-2 infection. The findings contribute valuable insights into the impact of the COVID-19 pandemic on high-energy therapy patients, highlighting potential implications for patient management during infectious outbreaks.

METHODS

The study was designated as a retrospective analysis of medical records of patients with ICD/CRT-D admitted to 2 high-volume hospitals due to high-voltage therapy. Admission to the ED was considered the same as admission to the hospital. A total of 36 patients (13.1%) were discharged home from the ED.

At the beginning of the COVID-19 pandemic, patients were mainly admitted to Infectious Disease Hospitals [3, 4]. By the beginning of September 2020, most patients requiring hospitalization were admitted to the nearest hospitals [18]. Only those patients requiring tertiary care procedures were referred to designated hospitals.

All admissions of these patients to the EDs during two 24-month periods were evaluated: 138 admissions in the pre-pandemic era (January 1, 2018–December 31, 2019) and 124 visits during the pandemic period (March 4, 2020–March 3, 2022).

Age, sex, therapy appropriateness, number of shocks, symptoms before shock that are presumed to provoke factors, comorbidities, the cause of ICD/CRT-D implantation, and SARS-CoV-2 swab test results in the pandemic era were gathered from electronic records. The time of the ICD intervention was assessed as before hospital admission or before and during hospitalization. The presence of dyspnea, fatigue, chest pain, vomiting, fever, or hemorrhage before the electrical shock was defined as the presence of symptoms not related to arrhythmia or ICD/CRT-D high-voltage therapy unless otherwise indicated. Loss of consciousness during electrical shock was considered arrhythmia-related. The presence of electrical shocks during hospitalization was assessed based on the medical recordings. Furthermore, the following procedures: ventricular ablation, supraventricular arrhythmia ablation: (pulmonary vein isolation, tricuspid isthmus ablation, ablation of the atrioventricular junction, ablation of the slow pathway of the atrioventricular node), coronary artery catheterization, coronary angioplasty, amiodarone or lidocaine administration during hospitalization were noted. The medical records of the patients were looked for general anesthesia of the patients aiming to treat electrical shocks.

In the case of the patients who died in the hospital, the first recorded rhythm during the last cardiac arrest was noted.

The therapy for COVID-19 was conducted as recommended by Polish experts [19, 20].

The ED at the University Hospital and the ED at the 4th Military Hospital are 2 of 4 EDs in Wrocław, a principal city of the Lower Silesia voivodeship with approximately 800 000 inhabitants.

During the third and fourth wave of the pandemic, the 4th Military Hospital was designated as the regional center for the treatment of patients with SARS-CoV-2 infection who needed treatment with pacemaker implantation, ablation, coronary angiography, angioplasty, or cardiac surgery.

The main outcome was all-cause mortality. Survival until hospital discharge was assessed based on the hospital records, and medium-term survival was assessed on the basis of the data obtained from the Ministry of Digitalization on October 24, 2022. The patients lost to follow-up were assessed as alive at the last contact (censored data).

Statistical analysis

Statistical analyses were carried out with standard statistical software (Statistica version 13, TIBCO Software Inc., Palo Alto, CA, US). Continuous variables were presented as mean and standard deviation for normally distributed data and as the median and interquartile range (IQR) for non-normally distributed data. Student's t-test and the Mann-Whitney U test were used for the statistical analysis of the differences, respectively. Categorical variables were presented as numbers and percentages and compared with the chi-squared test with Yates correction if necessary.

Survival after the hospital stay was assessed as survival until hospital discharge and one-month and 6-month survival. For these analyses, all visits were taken into account. For medium-term survival analysis, only the patient's last visit was considered. A Cox regression model was used to perform univariable and multivariable analyses. The covariates of the multivariable regressions were selected based on univariable regression results. Two models were built. The stepwise multivariable regression result was presented. The first model included demographics, past medical history data that were significant in the univariable analysis, the pandemic period, and used invasive procedures during hospitalization. The second model included demographics, number of shocks, and symptoms before shock(s).

Furthermore, the third model was built to assess the survival of patients for whom the last visit was during the pandemic period. The model included all the variables relevant to the first model and the presence of SAR-CoV-2 infection. *P* less than 0.05 was considered significant.

RESULTS

Demographics

The study group consisted of 198 patients (36 women, 162 men) aged 65.6 (standard deviation 12.8 years, range of 20–90 years.)

Hospital visits during pre-pandemic and pandemic period

During the study period, 149 patients had one visit due to electrical shock, 36 had 2 visits, 11 had 3 visits, and 2 had 4 visits. A group of 25 patients were admitted to the EDs during the pre-pandemic and pandemic era, and 173 patients were admitted only during the pandemic or pre-pandemic era. The first visit of 115 patients was in the pre-pandemic era, and 83 patients' first visit was during the pandemic era. The last admission to the hospital during the study period was during the pre-pandemic era in 90 (45.5%) cases, whereas 108 (54.5 %) patients were admitted during the pandemic. A total of 115 patients had at least one admission to the hospital before the pandemic, and 108 patients had at least one admission during the pandemic.

There were 262 admissions during the study period: 138 (52.7%) admissions before the pandemic and 124 (47.3%) during the pandemic. The 14 visits involving patients with a positive test for SARS-CoV-2 infection occurred in 14 different patients: in 12 cases as the only visit, in one case as the first visit but not the last visit, and in one case as neither the first nor the last visit during the study period.

The number of admissions before the pandemic and during the pandemic in the 4th Military Hospital was 89 and 91, respectively, whereas the number of admissions to the University Hospital was 49 and 33, respectively ($P = 0.21$).

Clinical characteristics

A comparison of clinical characteristics of the patient visits before and during the pandemic is presented in Table 1. There were no significant differences in age, sex, shock count, appropriateness of the therapy, or hospital survival.

In Table 2, a comparison of the clinical characteristics of 90 patients' whose last visit was during the pre-pandemic and 108 patients whose last visit was during the pandemic era was presented.

Table 3 presents a comparison of clinical characteristics of visits during the pandemic of patients with and without SARS-CoV-2 infection. The patients with SARS-CoV-2 infection had hospital shocks more often and had higher hospital mortality. Furthermore, the patients with SARS-CoV-2 infection more often had complaints before electrical discharge than did the patients without that infection. Dyspnea was reported by patients with SARS-CoV-2 infection nearly 3 times more frequently than by patients without SARS-CoV-2 infection. Among 14 patients with SARS-CoV-2 infection, the admis-sion was *via* Emergency Medical Services (EMS) in 3 cases, transfer from an outpatient clinic in 3 cases, transfer from another hospital department in 5 cases, and of their own accord in 3 cases.

The comparison of patients with and without COV-ID-19 during the pandemic era is presented in Table 4. The patients admitted with COVID-19 disease had more often symptoms not related to ICD/CRT-D discharge and higher levels of C-reactive protein.

Before the pandemic, 115 patients were admitted at least once, and 2 of them died. During the pandemic,

Table 1. Comparison of the details of patients' visits before and during the pandemic

	Pre-pandemic era n = 138	Pandemic era n = 124	*P*-value
Age, years, median (IQR)	68 (61–74)	67 (61–73)	0.30
Male, n (%)	114 (82.6)	102 (82.3)	0.94
Secondary prevention, n (%)	49 (33.5)	46 (37.1)	0.62
CRT-D, n (%)	32 (23)	29 (23)	
ICD, n (%)	105 (76)	90 (1)	
S-ICD, n (%)	1 (1)	5 (4)	0.18
Number of shocks before admission, median (IQR)	2.5 (1–6)	2 (1–6)	0.76
Appropriate, n (%)	98 (71.0)	91 (73.4)	0.67
Non-appropriate, n (%)	34 (24.6)	30 (24.2)	0.93
Appropriate and non-appropriate, n (%)	6 (4.4)	3 (2.4)	0.39
IHD, n (%)	97 (70)	80 (65)	0.13
HCM, n (%)	2 (1)	9 (7)	
DCM, n (%)	36 (26)	32 (26)	
Others, n (%)	3 (2)	3 (2)	
ICD/CRT-D discharges during hospitalization, n (%)	16 (12)	20 (16)	0.29
Arrival by EMS, n (%)	88 (64)	61 (49)	0.12
Chest pain before the shock, n (%)			
Ventricular ablation, n (%)	25 (18.1)	14 (11.3)	0.12
Supraventricular arrhythmia ablation, n (%)	3 (2.2)	3 (2.4)	0.92
Coronary angiography, n (%)	57 (41.3)	41 (33.1)	0.17
Coronary angioplasty, n (%)	16 (11.6)	12 (9.7)	0.62
Amiodarone, n (%)	42 (30.4)	39 (31.5)	0.86
Lidocaine, n (%)	3 (2.2)	8 (6.5)	0.16
External cardioversion, n (%)	2 (1.5)	3 (1.4)	0.90
In hospital mortality, n (%)	2 (1.4)	7 (5.5)	0.13
6-month mortality, n (%)	13 (9)	17 (14)	0.28

Abbreviations: CRT-D, cardiac resynchronization therapy defibrillator; DCM, dilated cardiomyopathy; EMS, Emergency Medical Services; HCM, hypertrophic cardiomyopathy; ICD, implantable cardioverter defibrillator; IHD, ischemic cardiomyopathy; IQR, interquartile range; S-ICD, subcutaneous ICD

Table 2. Comparison of 90 patients whose last visit took place in the pre-pandemic period and 108 whose last visit took place during the pandemic (only the parameters related to the last visit of each patient were analyzed)

	Pre-pandemic era n = 90	Pandemic era n = 108	*P*-value
Age, years, median (IQR)	68 (61–73)	67 (61–73)	0.57
Male, n (%)	74 (82)	88 (81)	0.89
Secondary prevention, n (%)	35 (39)	40 (37)	0.52
CRT-D, n (%)	69 (77)	76 (70)	0.40
ICD, n (%)	20 (22)	28 (26)	
S-ICD, n (%)	1 (1)	4 (4)	
Number of shocks before admission, median (IQR)	2.5 (1–6)	2.5 (1–7)	0.45
Appropriate, n (%)	62 (69)	78 (72)	0.37
Non-appropriate, n (%)	23 (26)	28 (26)	
Appropriate and non-appropriate, n (%)	5 (6)	2 (2)	
IHD, n (%)	59 (66)	70 (65)	0.69
HCM, n (%)	2 (2)	6 (6)	
DCM, n (%)	26 (29)	29 (27)	
Others, n (%)	3 (3)	3 (3)	
ICD/CRT-D discharges during hospitalization, n (%)	8 (9)	16 (15)	0.20
Arrival by EMS, n (%)	57 (63)	55 (51)	0.23
Ventricular ablation, n (%)	14 (16)	13 (12)	
Supraventricular arrhythmia ablation, n (%)	2 (2)	1 (1)	0.87
Coronary angiography, n (%)	35 (39)	34 (31)	0.28
Coronary angioplasty, n (%)	10 (11)	9 (8)	0.51
Amiodarone, n (%)	26 (29)	34 (31)	0.69
Lidocaine, n (%)	1 (1)	7 (6)	0.12
External cardioversion, n (%)	0 (0)	2 (2)	0.60
In hospital mortality, n (%)	2 (2)	7 (7)	0.27
6-month mortality, n (%)	13 (15)	16 (15)	0.89

Abbreviations: see Table 1

Table 3. Comparison of the details of patients' visits with and without coronavirus disease 2019 (COVID-19)

	Non-COVID-19 n = 110	COVID-19 n = 14	*P*-value
Age, years, median (IQR)	67 (61–73)	67 (58–67)	0.82
Sex, male, n (%)	89 (80.9)	13 (92.9)	0.46
Number of shocks before admission, median (IQR)	2 (1–7)	2 (1–4)	0.53
Shocks			
• appropriate, n (%)	81 (73.6)	10 (71.4)	0.86
• non-appropriate, n (%)	26 (23.6)	4 (28.6)	
• both, n (%)	3 (2.7)	0 (0)	
ICD/CRT-D discharges during hospitalization, n (%)	12 (10.9)	8 (57.1)	<0.001
Arrival by EMS, n (%)	58 (52.7)	3 (21.4)	0.06
In-hospital mortality, n (%)	3 (2.7)	4 (28.6)	<0.001
Ventricular ablation, n (%)	13 (11.8)	1 (7.1)	0.94
Supraventricular ablation, n (%)	2 (1.8)	1 (7.1)	0.77
Coronary angiography, n (%)	39 (35.5)	2 (14.3)	0.20
Coronary angioplasty, n (%)	12 (10.9)	0 (0)	0.42
Amiodarone, n (%)	32 (29.1)	7 (50.0)	0.11
Lidocaine, n (%)	6 (5.5)	2 (14.3)	0.49
External cardioversion, n (%)	2 (1.8)	1 (7.1)	0.77

Abbreviations: see Table 1

Table 4. Comparison of patients with and without coronavirus disease (COVID-19) during the pandemic

	Non-COVID-19 n = 110	COVID-19 n = 14	*P*-value
Symptoms not related to ICD/CRT-D discharge, n (%)	35 (31.8)	10 (71.4)	0.009
C-reactive protein, ng/ml, median (IQR)	2.7 (0.6-8.2) n = 103	13.4 (1.9–36) n = 14	0.007
Potassium (mEq/l), median (IQR)	4.1 (3.8–4.3) n = 107	4.1 (3.8–4.4) n = 14	0.87
NT-proBNP, pg/ml	1988 (622-4958) n = 97	4253 (1463-6834) n = 14	0.11
IHD, n (%)	72 (65.5)	8 (57.1)	0.75
HCM, n (%)	6 (5.5)	3 (21.4)	0.10
DCM non-IHD, n (%)	29 (26.4)	3 (21.4)	0.94
Long QT, n (%)	2 (1.8)	0	0.54
AF, n (%)	72 (65.5)	11 (78.6)	0.50
DM, n (%)	37 (33.6)	3 (21.4)	0.54
CKD, n (%)	21 (19.1)	2 (14.3)	0.94
COPD, n (%)	6 (5.5)	1 (7.1)	0.72
Stroke, n (%)	15 (13.6)	0 (0)	0.30
Cancer, n (%)	10 (9.1)	0 (0)	0.51

Abbreviations: AF, atrial fibrillation (chronic, paroxysmal, persistent); CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus, NT-proBNP, N-terminal pro-B-type natriuretic peptide; other — see Table 1

108 patients were admitted at least once, and 7 of them died ($P = 0.10$).

Implanted devices

The distribution of the implanted devices in the pre-pandemic and pandemic periods is presented in Tables 1 and 2. There were 6 admissions in 5 patients with implanted subcutaneous ICD (S-ICD) — one admission during the pre-pandemic period and 5 admissions during the pandemic period. Three admissions were related to inadequate electrical shocks. All the patients with implanted S-ICD admitted during the pandemic had negative SARS-CoV-2 tests.

Follow-up

All but 2 patients who were lost to follow-up were followed until October 24, 2022. Survival for these patients was assessed as one day, and their survival data were considered censored. The median time of follow-up from the first visit to the hospital due to electrical shock during the study period was 712 (IQR, 360–1125) days. The median time of follow-up from the last visit to the hospital due to electrical shock was 558 (IQR, 309–982) days.

In-hospital mortality

The total in-hospital mortality was 9; including 2 patients died during the pre-pandemic period and 7 during the pandemic period. Among patients who died in the hospital during the pandemic period, 4 had COVID-19 disease. None of the patients who died had incessant ventricular arrhythmia. The deaths were due to multiorgan failure in 7 cases, and the first recorded rhythm during their last cardiac arrest was asystole in 3 cases, pulseless electrical activity in 3 causes, and ventricular fibrillation in one patient in whom after defibrillation asystole occurred, and there was no return of any electrical activity. One patient who was brought by EMS during ongoing resuscitation had asystole on admission. The analysis of the memory of his ICD revealed that the electrical shocks were triggered probably by chest compressions and the cardiac arrest was not caused by ventricular arrhythmia.

Medium-term mortality

During the 30 days after the last visit, 8 patients died: 1 before the pandemic era and 7 during the pandemic. These numbers constituted 0.7% of the patients who had at least one visit before the pandemic and 6.5% of the patients with at least one visit during the pandemic ($P = 0.059$).

During the 6-month follow-up, 29 (15%) patients died: 13 (15%) with the last visit before the pandemic and 16 (15%) with the last visit during the pandemic ($P = 0.92$).

During the follow-up, 42 (47%) patients whose last visit was before the pandemic died as well as 24 (22%) patients whose last visit was during the pandemic. However, the follow-up duration of the non-survivors during the pandemic was significantly lower than before the pandemic (126.5 [IQR, 21–202.5] vs. 446 [IQR, 144–721] days; $P < 0.001$).

In Table 5, the univariable Cox regression analysis is presented.

The multivariable proportional hazards Cox regression analysis of the first model presented in Table 6 revealed that medium-term survival depends on the patient's age, heart failure (HF) decompensation in the medical history, and ejection fraction, but not on the period (pandemic vs. pre-pandemic) of the study.

The analysis of the second model which included demographics, number of shocks before admission, period of the study (pandemic vs. pre-pandemic), and symptoms before the shocks demonstrated that survival was decreased when electrical shocks were preceded by dysponea (HR, 3.428; 95% CI, 2.090–5.624; $P < 0.001$) or diarrhea (HR, 9.719; 95% CI, 4.075–23.176; $P < 0.001$)

The analysis of medium-term survival only of the patients whose last visit was during the pandemic period indicated that survival in this subgroup was related to the patient's age, HF decompensation in the medical history, and the presence of Sar-CoV-2 infection (Table 7).

DISCUSSION

Cardiac arrhythmias were found in 10%–20% of hospitalized COVID-19 patients [21]. Cardiac involvement and/or the effects of fever, inflammation, and hypoxia caused by any critical illness may account for this association [22]. Also, patients' underlying susceptibility to arrhythmia may modulate their occurrence. The most common arrhythmia found during COVID-19 was AF, whereas ventricular tachyarrhythmias were reported less frequently [7]. AF with rapid ventricular response and ventricular tachyarrhythmia in patients with ICD/CRT-D may lead to shock delivery, prompting patients to attend the ED.

The study's first finding was that the number of admissions to the ED due to ICD/CRT-D electrical shocks has not increased during the pandemic. The finding is in contrast with the results of the retrospective analysis of Adabag et al. [14], who reported an increase in the number of device high-energy interventions. Contrary to Adabag et al., O'Shea et al. [15] reported fewer electrical shocks during the pandemic. Furthermore, other authors found no significant difference in the occurrence of ICD therapies between pre-pandemic and pandemic periods [23]. Notably, in our study, we investigated the number of ED admissions, not the total number of patients experiencing electrical shocks. Therefore, the reason for the slightly decreased number of ED admissions may not reflect changes in the total number of electrical shocks in that population. Patients' reluctance to attend the ED may have decreased the number of admissions [24].

Furthermore, the number of electrical shocks unrelated to ventricular arrhythmia increased during the last phase of life [25]. During the pandemic, transportation to a tertiary care center for patients with multiorgan failure was considered unnecessary. Patients with an implanted ICD/CRT-D often have pre-existing HF [26]. The mortality rate during the pandemic of patients with pre-existing heart disease increased [27]. Therefore, it can be presumed that the size of the susceptible population may have decreased with each pandemic wave. Finally, the timing should be taken into account. In a report by Tajstra et al. [28], in Poland, during the early pandemic phase, the number of high-energy interventions did not change compared to the reference period, which may have been related to the low number of infected patients. Contrary to this report, Ducceschi et al. [29] reported that in Italy, the second-most affected country in the world after China, at the beginning of the pandemic, the percentage of patients with ventricular tachycardia/ventricular fibrillation doubled.

The second finding was that the percentage of patients with SARS-CoV-2 infection among patients with ICD/CRT-D shocks was about 10%. The percentage of patients with SARS-CoV-2 infection was higher than in the general population of ED patients in the same region, which during the third wave was reported to be 6.5% [30]. This finding aligns with the assumption that the occurrence of shocks increases during the infection.

The third finding was that patients with SARS-CoV-2 infection admitted to the ED due to electrical shock had higher in-hospital and medium-term mortality than those without the infection. This finding is concordant with reports of other authors who found that patients with acute cardiovascular disorders and concomitant SARS-CoV-2 infection have a worse prognosis than those without SARS-CoV-2 infection [31–33].

Comparing the clinical presentation of patients with and without COVID-19, we found that patients with

Table 5. Univariable Cox regression analysis for median-term survival

	Variable	HR (95% CI)	*P*-value
Demographics	Age (1 year)	1.038 (1.017–1.060)	<0.001
	Male sex	1.399 (0.740–2.643)	0.30
Studied period	Pandemic period	0.793 (0.485–1.297)	0.36
Location	University Hospital	1.133 (0.713–1.802)	0.60
Symptoms before and during CV	Lack of symptoms preceding CV	0.397 (0.256–0.617)	<0.001
	TLOC at CV	0.999 (0.515–1.939)	0.10
	Pain before CV	0.567 (0.179–1.797)	0.34
	Dyspnea	3.069 (1.887–4.991)	<0.001
	Fatigue	2.158 (1.230–3.785)	0.007
	Infection	1.872 (0.900–3.891	0.09
	Bleeding	7.348 (2.658–20.319	<0.001
	Diarrhea	7.334 (3.126–17.208)	<0.001
Probable cause	Acute heart ischemia	0.570 (0.140–2.319)	0.43
	Heart failure decompensation	4.376 (2.445–7.831)	<0.001
	Electrolytes imbalance	1.656 (0.721–3.807	0.24
	Secondary prevention	1.067 (0.808–1.408	0.65
HVT details	HVT total number Inappropriate	0.970 (0.915–1.029)	0.31
	HVT	0.823 (0.491–1.377)	0.46
Disease underlying ICD/CRT-D implantation	Ischemic cardiomyopathy Non-	1.123 (0.696–1.813)	0.634
	ischemic	1.001 (0.608–1.648)	0.10
	HCM	1.042 (0.328–3.310)	0.94
Concomitant diseases	CKD	1.364 (0.788–2.360)	0.27
	DM	1.978 (0.618–1.549)	0.93
	COPD	2.112 (1.116–3.997)	0.02
	Cancer	2.975 (1.477–5.990)	0.002
	Stroke	0.896 (0.448–1.793)	0.76
Echocardiography	EF	0.943 (0.920–0.967)	<0.001
Medical history	Heart failure decompensation	2.886 (1.860–4.478)	<0.001
	AF/AFL	1.875 (1.146–3.067)	0.01
	RBBB	0.439 (0.578–3.577)	0.43
	LBBB	2.232 (1.269–3.924)	0.005
ECG on admission	AF	1.393 (0.896–2.164)	0.14
	VT	2.431 (0.979–6.033)	0.06
In-hospital procedures	Ventricular ablation	0.930 (0.503–1.718)	0.82
	Supraventricular ablation	0.435 (0.060–3.125)	0.41
	Coronary angiography Coronary	0.784 (0.495–1.241)	0.30
	angioplasty Amiodarone	0.487 (0.197–1.203)	0.12
	Lidocaine	1.710 (1.092–2.677)	0.02
	External cardioversion	1.086 (0.342–3.445)	0.90
		All patients who had external cardioversion survived, and HR could not be calculated	

Abbreviations: AFL, atrial flutter; CI, confidence interval; CV, electrical shock; HR, hazard ratio; HVT, high-voltage therapy; LBBB, left bundle branch block; RBBB, left bundle branch block; TLOC, transient loss of consciousness; VT, ventricular tachycardia; other — see Tables 1 and 4

Table 6. Stepwise multivariable Cox regression analysis for survival in model 1 (only the parameters related to the last visit of each patient were analyzed)

	HR (95% CI)	*P*-value
Age (per year)	1.025 (1.001–1.049)	0.045
EF (per 1%)	0.953 (0.928–0.979)	<0.001
Cardiac decompensation in MHx	1.960 (1.185–3.244)	0.009

Abbreviations: EF, ejection fraction; MHx, medical history; other — see Table 5

Table 7. Stepwise multivariable Cox regression analysis for survival in the subgroup of patients who had the last visit during the pandemic in model 3 (only the parameters related to their last visit were analyzed)

	HR (95% CI)	*P*-value
SARS-CoV-2 infection	3.604 (1.322–9.822)	0.012
Age (per year)	1.052 (1.006–1.100)	0.025
Cardiac decompensation in MHx	2.600 (1.137–5.947)	0.025

Abbreviations: SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; other — see Tables 5 and 6

SARS-CoV-2 infection rarely had an ICD/CRT-D electrical shock that was not preceded by symptoms of infection. Moreover, the patients with a SARS-CoV-2-positive test had higher C-reactive protein levels. Furthermore, the hospital observations indicated a higher number of ICD/CRT-D discharges in patients with SARS-CoV-2 infection than in those with a negative test. These findings indicate that the predisposing factor in patients with COVID-19 is related to the infection and persists after admission, resulting in further ICD/CRT-D shocks. These findings concur with the assumption of Adabag et al. [14] that the missing links between the substrate of HF and ICD/CRT-D discharges are in the transient factors, like viral infections, which can exacerbate the patient's condition and trigger an arrhythmia.

Furthermore, the assessment of the timing of the electrical shocks in patients with SARS-CoV-2 indicates that the electrical shocks are triggered after the onset of infection symptoms. This finding aligns with the case report of Mitacchione et al. [34] presenting the timeline of SARS-CoV-2 infection, ventricular arrhythmia, and electrical shocks. These authors found that ventricular arrhythmia occurred at the onset of the infection, 20 days before hospital admission, but the electrical storm occurred on the 8th day of hospitalization [34]. Hypoxia-induced intracellular calcium overload leading to early afterdepolarization was considered to be the mechanism of ventricular arrhythmia [34]. Also, Kasinadhuni et al. [35] reported an electrical storm event in a patient on the 5th day of SARS-CoV-2 infection. The patient's electrolyte level was within normal limits. Electrolyte disturbances seem to be less critical in ventricular arrhythmia occurrence in patients with SARS-CoV-2 infection. In the present study, dyselectrolytemia was found in a similar percentage of patients with and without the infection. SARS-CoV-2 infection may trigger ventricular arrhythmias via cytokines like interleukin-6, interleukin-1, or tumor necrosis factor-α, which can modulate K^+ and/or Ca^{2+} channels and prolong the potential duration of their action [36].

The frequency of cardiologic procedures like catheter ablation, coronary catheterization, and angioplasty did not differ between the pre-pandemic and pandemic periods. During the pandemic, temporary deferment of non-urgent elective electrophysiological procedures was recommended [37]. However, invasive procedures in patients with electrical shocks during the COVID-19 pandemic were considered life-saving and, therefore, were performed.

The mortality rate increased during the pandemic in the whole world [37]. In 2020 in Poland, the excess of deaths was about 15%, whereas, for example, in Austria, it was 7.6% [38]. The difference could have resulted from a higher disease burden in Polish society than the average for European Union countries. Other factors related to excess mortality could have been difficult access to healthcare services during the pandemic and an ineffective pro-vaccination campaign. However, our data indicate that the increased in-hospital death rate in patients admitted due to electrical shocks was related only to SARS-CoV-2 infection.

An additional finding of the study is that the number of patients with S-ICD was higher in the pandemic period in comparison to the period before the pandemic, which is concordant with data presented by Kempa et al. [39] that showed increasing number of S-ICD implantations in Poland.

Limitations

The main limitation of the study is its retrospective character. Furthermore, based on the recorded data, multiple shocks could not be distinguished because one episode from multiple shocks of recurrent ventricular tachyarrhythmias met the electrical storm criteria. During the pandemic, in EDs, it was not possible to record all data.

The impact of the lockdown on easy access to drug prescriptions, cardiovascular drug compliance, and patients' decision to call an ambulance or transfer to the ED cannot be validated. Another limitation is that the prevalence of electrical shocks may be underestimated due to lack of remote control and monitoring of implantable electronic devices.

Moreover, the studied groups were relatively small. Because of the small size of the group of COVID-19 patients, the impact of COVID-19 therapy was not analyzed in this study.

CONCLUSIONS

The admissions to the ED during the SARS-CoV-2 pandemic for ICD/CRT-D shocks remained on the same level as before. During the 2 years of the COVID-19 pandemic, among patients with ICD/CRT-D discharges treated in the hospital, about 10% had a positive SARS-CoV-2 smear test. Patients with SARS-CoV-2 infection had more frequent symptoms unrelated to arrhythmia or ICD/CRT-D discharge before admission, electrical discharges from ICD/CRT-D during hospitalization, and higher mortality than non-COVID patients. Patients with SARS-CoV-2 infection also had higher C-reactive protein levels but did not differ in other studied laboratory parameters from those without the infection.

Article information

Conflict of interest: None declared.

Funding: None.

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