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Mortality and Risk of Cardiac Complications following Accidental Electric Shock: A Nationwide Cohort Study

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Abstract

Objective: The exposure to electric shock has been associated with an increased risk of developing delayed cardiac arrhythmias and cardiac diseases. Compared with the general Danish population, we examined whether electric shock patients have an increased risk of developing cardiac disease, cardiac arrhythmias, or death.

Design: Matched cohort study.

Setting: A nationwide study in Denmark from 1994 to 2011.

Participants: We identified 11,462 Danish patients who visited an emergency ward or were admitted at a hospital due to electric shock from 1994 to 2011. Each patient was matched on age and sex with five random controls from the Danish population.

Main outcome measures: Mortality, cardiac procedures, and cardiac diseases following electric shock.

Results: The electric shock patients comprised 7,390 patients seen at the emergency ward and 4,072 patients who were admitted to a hospital. The median age was 28.6 years (21.3 to 37.7) for emergency ward patients and 26.4 years (18.3 to 37.4) for admitted patients. In both groups, most patients were male (74.0% vs. 76.8%, respectively). Few of the electric shock patients had a record of cardiovascular disease at baseline (364 of 11,462, 3.2%).

The five-year cumulative incidence of death was 0.47% (95%CI 0.29% to 0.65%) for emergency ward patients and 1.04% (95%CI 0.71% to 1.37%) for admitted patients. When compared to the matched controls no difference in five-year survival was observed (p=0.10 for emergency ward patients vs. controls and p=0.80 for admitted patients vs. controls). Less than four patients received a pacemaker within 30 days.

Conclusions: This large nationwide study did not demonstrate an increase in mortality among patients seen at hospitals after accidental electric shock. Furthermore, cardiac procedures and diseases following the electric shock were very rare. We suggest that nearly all patients can be discharged safely from the emergency room after electric shock without further observation.

Keyworks: electric shock, electric injury, delayed arrhythmia, cardiac disease

Strengths and limitations of this study:

- A nationwide matched cohort study comparing electric shock patients with the general Danish population whether the electric shock patients had an increased risk of developing cardiac disease, cardiac arrhythmias, or death.
- Nationwide administrative registries were used to assess comorbidities, patient characteristics, and outcomes.
- Case files for patients with electric shock who had a cardiac procedure or cardiac complication, within 30 days following the electric shock, were reviewed to evaluate whether the complication seemed related to the electric shock.
- Information about the clinical evaluation that resulted in a hospital admission or discharge from the emergency department was not available in our study, including voltage exposure.

Introduction

Electric shock can cause immediate respiratory and cardiac arrest.[1,2] Furthermore, clinical cases have reported an increased risk of developing delayed arrhythmias following electric shock[3–6] and electrical shock has been associated with the development of heart failure[7], cardiomyopathy[8] and myocardial infarction.[9–11] Consequently, a variety of recommendations and clinical approaches have been suggested and usually patients with identified risk factors such as syncope, ECG changes or high-voltage shock are hospitalized for 24-48 hours for cardiac monitoring.[2,12–16] However, the incidence of late serious arrhythmias and cardiac complications has proven difficult to document in both small prospective[12,17] and retrospective cohort studies[18,19], and little is known about the long-term consequences for survivors who arrive at emergency wards or are admitted for observation. As such, current clinical practice is not based on evidence and admission of multiple patients after electric shock is a strain for the patients, employers, and the health care system.

In this study, we identified all Danish patients who visited an emergency ward or were admitted at a hospital due to electric shock over a period of 18 years to examine if late arrhythmias had occurred, the exposed patients had an increased risk of developing cardiac disease, or increased risk of death compared with matched individuals from the general Danish population.

Method

Study design and population

We performed a nationwide matched cohort study on patients in Denmark who had suffered an electric shock between 1994 and 2011. Patients with electric injuries were identified as having received a diagnosis of electric shock (ICD-10 codes: DT754, DT754A, DW85, DW86, DW87) from an emergency ward, hospital admission, or as a cause of death. The study patients were followed from the day of the electric shock until death or 31st December 2012. If a patient had more than one electric shock, only the first was considered in this study. The study cases exposed to an electric shock were matched on age and sex with five individuals randomly chosen from the Danish population. Matched controls were alive the same month as the associated case was exposed to the electric shock. The matched controls were followed from the day the associated case was exposed to the electric shock.

We excluded the following patients: Patients exposed to lightning and patients who were dead at hospital arrival following the electric shock.

Patient characteristics at baseline

Data on age, sex, and vital status were obtained from the Danish Civil Registration System. Admission dates, discharge dates, and discharge diagnosis were gathered from the Danish National Patient Registry. Information on causes of death were collected from the Danish Register of Causes of Death. Cardiac diagnosis and cardiac procedures were obtained from the National Patient Register. Diagnoses were available from 1977. An ICD-8 classification was used until 1994. From 1994 and forth, ICD-10 was used. Cardiac procedures were available from 1996. Based on this information, we identified any diseases or cardiac procedures until ten years before start of follow-up as baseline information. Table 1 in the supplementary material contains details on the specific ICD-8, ICD-10 codes, and procedure codes used to define comorbidities or prior procedures at baseline before the electric shock.

Study outcomes

The primary outcome was five-year mortality for cases and controls. Secondary outcomes were the number of exposed patients compared with controls, who underwent a cardiac procedure, or received a diagnosis of a new cardiac disease or arrhythmia within a period of 30 days and 31 to 365 days after the electric shock.

Cardiac complications and procedures after electric shock

Procedures included newly implanted pacemakers and temporary pacemakers (procedure codes “BFCA0”, ”BFCA01”, “BFCA02”, “BFCA03”, “BFCA04”, “BFCA05”, “BFCA06”, “BFCA07”,”BFCA9”) or newly implanted ICDs (procedure codes “BFCB0”, “BFCB00”, “BFCB01”, “BFCB02”, “BFCB03”); All radiofrequency ablation (RFA) procedures (“BFFB”); All cardiac revascularization treatments including PCI procedures (“KFNG00”, “KFNG02”, “KFNG05”, “KFNG10”, “KFNG12”); and coronary artery bypass grafting (CABG) procedures (“KFNA”, “KFNB”, “KFNC”, “KFND”, “KFNE”).

Cardiac complications were identified using ICD-10 diagnosis codes. These comprised acute myocardial infarction (AMI) (“I21”), pericarditis and other pericardial diseases (“I30”, “I31”), acute myocarditis (“I40”), cardiomyopathy (“I42), atrio-ventricular (AV)-block (“I44.0”, ”I44.1”, “I44.2”, “I44.3”), bundle branch block (BBB) (“I44.4”, “I44.5”, “I44.6”, “I44.7”, “I45.0”, “I45.1”, “I45.2”, “I45.3”, “I45.4”), sick sinus syndrome (SSS) (“I49.5”), supraventricular tachycardia (SVT) (“I47.1”), ventricular tachycardia (VT) (“I47.2”), ventricular fibrillation (“I49.0”), atrial fibrillation/atrial flutter (“I48”), and heart failure (HF) (“I50”).

For this study, results with patient numbers lower than 4 have been censored to ensure patient anonymity.

Patient case files

We obtained and reviewed 15 of 23 patient case files related to the electric shock of the patients who had a cardiac procedure or cardiac complication within 30 days following the electric shock (supplementary material).

Statistical methods

We divided the electric shock patients in two groups: The first group was patients discharged directly from the emergency ward without any further observation. We considered these patients at low-risk of cardiac complications. The second group was patients hospitalized and observed following the electric shock. We considered these patients at high-risk of cardiac complications.

Continuous variables were reported as medians and 1st to 3rd quartiles (Q1-Q3). Continuous variables were compared using the Kruskal-Wallis rank sum test. Event numbers were compared between the controls, emergency ward patients, and admitted patients using the Chi square test or the Fisher's Exact test. The incidence of electric shock patients was calculated as the number of electric shock patients per 100,000 Danish inhabitants at each year. The incidence 95% confidence intervals (CI) were calculated. Negative binomial regression was used to estimate temporal trends in incidences during the study period. Kaplan-Meier estimates were used to construct cumulative incidence of death curves. Two-sided p-values were reported.

Analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC) and R version 3.3.0.[20]

Ethics

The study was approved by the Danish Data Protection Agency (j.nr.: 2007-58-0015, internal reference GEH-2014-013, I-Suite nr.: 02731). Ethical approval is not required for retrospective registry-based studies in Denmark.

Allowance to identify and review the patient case files from the selected patients with a procedure or cardiac complication was obtained from the Danish Health Authorities according to Danish law (case ref. 3-3013-1054/1/). Further information is available in the supplementary material.

Patient involvement

The study idea was conceived based on several patient contacts in emergency departments who had been exposed to electric shock and were admitted for observation. In addition, several of the exposed patients expressed concerns whether they had an increased risk of developing cardiac diseases following the electric shock. No specific patients were involved in setting the research question nor involved in the study design, interpretation of the results, or writing the manuscript.

Results

The study population consisted of 11,462 patients. The selection process is available in figure 1. The exposed study groups comprised 7,390 patients in the emergency ward group and 4,072 patients in the admission group. The baseline demographic characteristics of the study patients and controls are available in table 1. The median age of the study patients was 28.6 (21.3 to 37.7) and 26.4 (18.3 to 37.4) years for emergency ward and admitted patients, respectively. In both groups, the majority of the patients were male with slightly more males in the admitted group. Overall, few of the study patients had a record of cardiovascular disease at baseline (364 of 11,462, 3.2%). However, compared with the controls there was a tendency for admitted patients to have a greater prevalence of cardiac disease at baseline although rare. The length of the hospital admission was one day or less for 95.5% (3,888 of 4,072) of the admitted patients. Of the patients admitted, 4.7 % (190 patients) were registered as having a burn injury. The incidence of electric shock patients increased from 3.9 per 100,000 persons (95%CI 3.4 to 4.5) in 1994 to 22.2 (95%CI 21.4 to 23.5) in 2011 (p<0.01). The increase was primarily due to an increase in patients seen at emergency departments (0.3 per 100,000 persons (95%CI 0.2 to 0.5) in 1994 to 16.8 (95%CI 15.7 to 17.9) in 2011, p<0.01), while the number of patients admitted increased less during the study period (3.3 per 100,000 persons (95%CI 3.1 to 4.1) in 1994 to 5.5 (95%CI 5.2 to 5.8) in 2011, p<0.01) (figure 2).

The five-year cumulative incidence of death was 0.47% (95%CI 0.29% to 0.65%) for emergency ward patients and 1.04% (95%CI 0.71% to 1.37%) for admitted patients. Figure 3A and 3B show the five-year cumulative incidence of death curves for the emergency ward and admitted patients compared with their matched controls. The overall mortality was low, and no difference in death was found between the emergency ward patients and admitted patients compared with the matched controls (P=0.10 and P=0.80, respectively).

Cardiac diseases and procedures

Table 2 illustrates the total number of cardiac procedures within 30 days and within 31-365 days after the electric shock. Within 30 days, less than four patients received a pacemaker. Overall, cardiac procedures were rare in the study population even one year after exposure to the electric shock.

Table 3 shows new cardiac diseases for cases and controls within 30 days and within 31-365 days after the electric shock. Overall, new cardiac diseases for both emergency ward and admitted patients were rare. The median age of the electric shock patients with atrial fibrillation within 30 days was 55.7 years (50.2 to 56.2). From 31 to 365 days after exposure, only heart failure, pericarditis, and ventricular tachycardia/fibrillation were different between the three study groups. For the 11 electric shock patients

with a diagnosis of heart failure within 31 to 365 days after exposure, 54.5% (6 of 11) had a record of ischemic heart disease or myocardial infarction.

Patient case file reviews

We were able to review 15 of 23 case files (65%) of patients who had a cardiac procedure or were registered as having cardiomyopathy, AV-block, sick sinus syndrome, ventricular tachycardia/ventricular fibrillation, or heart failure within 30 days after the electric shock. In three cases (20%), the case description was not detailed enough to conclude on the relationship between the shock and the subsequent cardiac procedure, arrhythmia, or cardiac disease. For the pacemaker implantations, none were related to the index electric shock. All the cardiomyopathies identified in relation to the electric shock were of familiar or hypertrophic origin and not related to the electric shock. All heart failure cases reviewed were related to previously unidentified ischemic heart disease. For patients with a ventricular tachycardia or ventricular fibrillation the arrhythmia occurred in direct relation to the electric shock and not as a delayed arrhythmia. All the VT/VF patients were resuscitated before hospital arrival. None of the sick sinus syndrome or AV-block diseases were considered a consequence of the electric shock. The above description has omitted detailed descriptions of the patient cases to ensure patient anonymity (see supplementary material).

Discussion

This large nationwide cohort study could not identify any excess mortality in patients exposed to electric shock compared to matched controls from the general population. This includes both patients who were admitted to a hospital and patients who were directly discharged from the emergency ward following the electric shock. Although very rare, we found a marginally increased risk of cardiac arrhythmias, heart failure and cardiomyopathy in those patients hospitalized, most likely due to observation bias.

Several case reports have suggested a risk of delayed cardiac complications following an electric shock among patients who initially survived the electric shock. Jensen et al.[3] described three patients who developed ventricular tachycardia and/or ventricular fibrillation with a delay after exposure to electric shock of both high and low voltage. Furthermore, cardiac biopsies showed fibrosis in the myocardium of these three patients. Other case reports have reported sick sinus syndrome occurring long after the exposure to electric shock[4], as well as atrial fibrillation[6,21] and bundle branch block [13]. Heart failure, cardiomyopathy, and myocardial infarction have also been reported as complications following electric shock[7,8,11]. Both myocardial damage and isolated damage to the hearts electrophysiological system have been suggested as explanations of the proposed higher risk of arrhythmia and heart failure following an electric shock [5,15,22]. In addition, elevated CK-MB and electrocardiogram abnormalities were reported as

frequent among electric shock patients in a Chinese study.[23] This suggests that exposure to electric shock might cause myocardial injury, hypothetically resulting in a higher mortality and morbidity among patients exposed to electric shock. However, this large study did not demonstrate any increased mortality for patients exposed to electric shock when compared to the general population.

Several studies have evaluated the risk of delayed arrhythmias and cardiac morbidity among patients exposed to electric shock both prospectively and retrospectively. A study by Searle et al.[19] found no serious delayed cardiac arrhythmias in the retrospective study of 268 patients admitted with electric injuries. Arrowsmith et al.[24] performed a retrospective study of 145 patients admitted. Four patients had minor cardiac abnormalities all present at the time of hospital admission. Bailey et al. [17] studied occurrence of late arrhythmias among 134 patients considered at high risk of cardiac complications. No patients developed potentially lethal late arrhythmias. Purdue et al. [14] considered retrospectively 48 admitted patients exposed to high-voltage (>1000V) shock. Furthermore, they followed 10 patients prospectively after exposure to high-voltage. They found two patients with myocardial infarction at the time of admission. No serious late arrhythmias occurred during observation. Blackwell et al. [12] considered prospectively the need of cardiac monitoring following electric shock on a study population of 186 patients (196 presentations) using a standardized protocol. No serious delayed arrhythmias were observed. Cunningham et al. [13] found no delayed arrhythmias in a retrospective study of 70 admissions following electric shock. Evidently, it has proven difficult to show an increased risk of delayed arrhythmias among electric shock patients. However, the previous studies have been relatively smaller in size. In our study, arrhythmias and cardiac diseases following the electric shock were very rare. Among the case files we reviewed, the cardiac diseases were unlikely to be because of the electric shock, as the diseases were of chronic nature not identified prior to the clinical evaluation related to the electric shock. Among the patients with an AV-block, none of the case files reviewed resulted in a pacemaker as a consequence of the electric shock. Atrial fibrillation/atrial flutter was more frequent among the electric shock patients than the control group. However, these patients had a higher median age than the rest of the electric shock patients. The risk of atrial fibrillation and undiagnosed silent atrial fibrillation increases with higher age.[25,26] Previously undetected atrial fibrillation might be the case for some of our study patients with atrial fibrillation because of the clinical examination following the electric shock. Furthermore, our study showed that during the longer follow-up from 31 days to 365 days the frequencies of the cardiac diseases including atrial fibrillation/atrial flutter were similar when comparing the electric shock patients to the controls, except for heart failure. However, most of these heart failure patients (54.5%) had a history of ischemic heart disease or myocardial infarction.

Events of VT and VF within 30 days happened almost entirely in the admission group. In all of the case files reviewed, the VT/VF happened in direct relation to the electric shock and not as a delayed arrhythmia. Consequently, we did not identify any patients with VT/VF occurring as a delayed arrhythmia after the electric shock.

Within 30 days after exposure, few patients in the admission group received a pacemaker. Patient case file reviews revealed that none of the cases could be related to the electric shock. In addition, the frequency of pacemaker procedures for the patients exposed to electric shock did not differ from the control group within the period from 31 days to 365 days following the electric shock.

We observed an increase in electric shock patients during the study period. The increase was mostly due to more electric shock patients being seen at emergency departments, while the number of admitted electric shock patients did not increase as much. We believe this to be related to a progressively lower threshold before going to the emergency department for clinical evaluation after minor risk electric shock.

Overall, our study cannot exclude a very small risk of delayed cardiac complications due to electric shock, but a likely explanation is an observer bias because of the fact that the electric shock patients were subject to a number of examinations that the control group did not receive. The fact that the observed arrhythmias were not associated with a significant effect on mortality and number of cardiac procedures, despite the large sample size, makes such an interpretation likely. In addition, this explanation seems likely based on the case file reviews.

This implies that patients exposed to electric shock can be discharged safely from the emergency ward unless there is an obvious cardiac injury, cardiac arrhythmia, the suggestion of an underlying previously undetected cardiac disease, or traumatic injury that require immediate treatment.

Limitations

A limitation of the present study is the observational design. As such, this study cannot evaluate the causal relationship between the complications and the electric shock. Importantly, mortality and cardiac complications were very rare supporting our conclusions that almost all patients without immediate cardiac complications or trauma are unlikely to suddenly die or develop a delayed cardiac disease because of the electric shock.

The number of electric shock incidents are likely an underestimation of the total number of electric shock incidents in Denmark during the study period as many victims are evaluated in the primary care health system without referral for secondary care evaluation or never make contact with the health care system.

However, any complications following electric shock in the general population would most likely have occurred in our study population as these patients were selected for further observation during a hospital admission or at the emergency ward.

We were unable to obtain all of the patient case files. However, the ones we evaluated did not prove an increased risk of delayed arrhythmias or cardiac diseases following the electric shock.

Information about the clinical evaluation that resulted in a hospital admission or discharge from the emergency department was not available in our study, including voltage exposure. However, the scope of this study was to evaluate risk of mortality and cardiac complications following an electric shock as based on an initial clinical evaluation on whether or not the patient needed observation and monitoring following the electric shock. Furthermore, previous studies have reported delayed cardiac arrhythmias happening both following low- and high voltage electric injuries (generally defined as below or above 1000V, respectively).[3,27]

This study was conducted in a western developed country and the results may not apply to developing countries.

Conclusion

This large nationwide study did not demonstrate an increase in mortality among patients seen at hospitals after accidental electric shock. Furthermore, cardiac procedures and diseases following the electric shock were very rare. We suggest that an observer bias can explain these observations and that nearly all patients can be discharged safely from the emergency room after accidental electric shock without requiring any further observation.

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None

Disclosures

All authors have completed the ICMJE uniform disclosure form.

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Author Contributions

The study was conceived by Steen Hansen, Christian Torp-Pedersen, Sam Riahi, and Søren Hjortshøj. Most analyses were performed by Steen Hansen with support from Rikke Mortensen. The initial manuscript draft was written by Steen Hansen. Christian Torp-Pedersen, Sam Riahi, Søren Hjortshøj, Lars Køber, Rikke Mortensen, and Peter Søgaard contributed in the interpretation of the data analyses and critical revisions of manuscript versions. Steen Hansen, Christian Torp-Pedersen, Sam Riahi, Søren Hjortshøj, Lars Køber, Rikke Mortensen, and Peter Søgaard have approved the final version of the manuscript.

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Figures

Figure 1

Selection process of the study population

Figure 2

Incidence of electric shock patients per 100,000 Danish inhabitants from 1994 to 2011

Legend: The incidence of electric shock patients per 100,000 Danish inhabitants during the study period from 1994 to 2011.

Figure 3A+3B

Mortality following electric shock for emergency ward and admitted patients

Legend: Cumulative incidence of death for electric shock patients discharged from the emergency ward (N=7,390) and admitted to a hospital (N=4,071). Each patient in the two patient groups were matched with five controls (age and sex) randomly identified from the Danish population. The controls were followed from the day the corresponding case was exposed to the electric shock. 3A shows the cumulative incidence of death for emergency ward patients compared with matched controls. 3B shows the cumulative incidence of death for admitted patients compared with matched controls.

Tables

Table 1: Baseline characteristics of electric shock patients and controls from the Danish population with comorbidities and prior cardiac procedures before the beginning of follow-up

Characteristics	Controls*	Emergency Ward	Admission	P-value
Count - no. (%)	57,310	7,390	4,072	
Median age in years (Q1, Q3)	28.0 (20.3, 37.7)	28.6 (21.3, 37.7)	26.4 (18.3, 37.4)	<0.01
Median Follow-up in years (Q1, Q3)	6.7 (3.5, 11.5)	5.8 (3.1, 10.1)	9.1 (4.8, 13.8)	<0.01
Male sex	42,960 (75.0)	5,466 (74.0)	3,127 (76.8)	<0.01
Ischemic heart disease (MI not included)	412 (0.7)	99 (1.3)	66 (1.6)	<0.01
Cerebrovascular disease	241 (0.4)	46 (0.6)	27 (0.7)	<0.01
Perifer vascular disease	102 (0.2)	12 (0.2)	9 (0.2)	0.77
Previous AMI	168 (0.3)	26 (0.4)	25 (0.6)	<0.01
Pericarditis	55 (0.1)	22 (0.3)	4 (0.1)	<0.01
Myocarditis	10 (0.0)	5 (0.1)	≤3 (≤0.1)	0.03
Cardiomyopathy	32 (0.1)	6 (0.1)	9 (0.2)	<0.01
AV-block	22 (0.0)	6 (0.1)	7 (0.2)	<0.01
Sick sinus syndrome	16 (0.0)	4 (0.1)	6 (0.1)	<0.01
Supraventricular tachycardia	115 (0.2)	30 (0.4)	26 (0.6)	<0.01
Ventricular tachycardia/fibrillation	29 (0.1)	9 (0.1)	8 (0.2)	<0.01
Atrial fibrillation/flutter	180 (0.3)	29 (0.4)	14 (0.3)	0.52
Heart failure	92 (0.2)	11 (0.1)	16 (0.4)	<0.01
Pacemaker	14 (0.0)	8 (0.1)	5 (0.1)	<0.01
ICD	13 (0.0)	≤3 (0.0)	6 (0.1)	<0.01

Radiofrequency ablation	40 (0.1)	10 (0.1)	5 (0.1)	0.11
CABG	49 (0.1)	6 (0.1)	≤3 (≤0.1)	0.96
PCI	67 (0.1)	12 (0.2)	7 (0.2)	0.40

All results are reported as the number of patients (%) unless otherwise specified. Q1, Q3, 1st+3rd quartiles

AMI, Acute myocardial infarction; AV, atrio-ventricular; ICD, Implantable Cardioverter Defibrillator; CABG, Coronary artery bypass grafting; PCI, Percutaneous coronary intervention

Patient numbers lower than 4 have been censored to ensure patient anonymity.

* The matched controls to admitted and emergency ward electric shock patients have been pooled in one group.

Table 2: Cardiac procedures following electric shock

Characteristics	**Controls***	**Emergency Ward**	**Admission**	**P-value**
Count - no. (%)	57,310 (100.0)	7,390 (100.0)	4,072 (100.0)	
< 31 days after exposure				
Pacemaker	0 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
ICD	0	0	0	NA
Radio Frequency Ablation	0	0	0	NA
CABG	0	0	0	NA
PCI	≤3 (0.0)	0 (0.0)	0 (0.0)	1
31-365 days after exposure				
Pacemaker	6 (0.0)	0 (0.0)	0 (0.0)	1
ICD	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	0.20
Radio Frequency Ablation	≤3 (0.0)	≤3 (0.0)	≤3 (≤0.1)	<0.01
CABG	≤3 (0.0)	≤3 (0.0)	≤3 (≤0.1)	0.02
PCI	14 (0.0)	≤3 (0.0)	≤3 (≤0.1)	0.41

All results are reported as the number of patients (%) unless otherwise specified.

ICD, Implantable Cardioverter Defibrillator; CABG, Coronary artery bypass grafting; PCI, Percutaneous coronary intervention.

Patient numbers lower than 4 have been censored to ensure patient anonymity.

* The matched controls to admitted and emergency ward electric shock patients have been pooled in one group.

Table 3: Cardiac diseases following electric shock				
Characteristics	**Controls***	**Emergency Ward**	**Admission**	**P-value**
Count - no. (%)	57,310	7,390	4,072	
< 31 days after exposure				
AMI	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	0.20
Pericarditis	0	0	0	NA
Myocarditis	0	0	0	NA
Cardiomyopathy	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
AV-block	≤3 (0.0)	0 (0.0)	8 (0.2)	<0.01
Sick sinus syndrome	0 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
Supraventricular tachycardia	0 (0.0)	≤3 (0.0)	4 (0.1)	<0.01
Ventricular tachycardia/fibrillation	≤3 (0.0)	0 (0.0)	7 (0.2)	<0.01
Atrial fibrillation/flutter	≤3 (0.0)	≤3 (0.0)	12 (0.3)	<0.01
Heart failure	≤3 (0.0)	≤3 (0.0)	0 (0.0)	0.52
31-365 days after exposure				
AMI	24 (0.0)	≤3 (0.0)	5 (0.1)	0.09
Pericarditis	7 (0.0)	≤3 (0.0)	≤3 (≤0.1)	0.04
Myocarditis	≤3 (0.0)	0 (0.0)	0 (0.0)	1
Cardiomyopathy	9 (0.0)	0 (0.0)	≤3 (≤0.1)	0.14
AV-block	4 (0.0)	0 (0.0)	≤3 (≤0.1)	0.09
Sick sinus syndrome	4 (0.0)	0 (0.0)	≤3 (≤0.1)	0.34

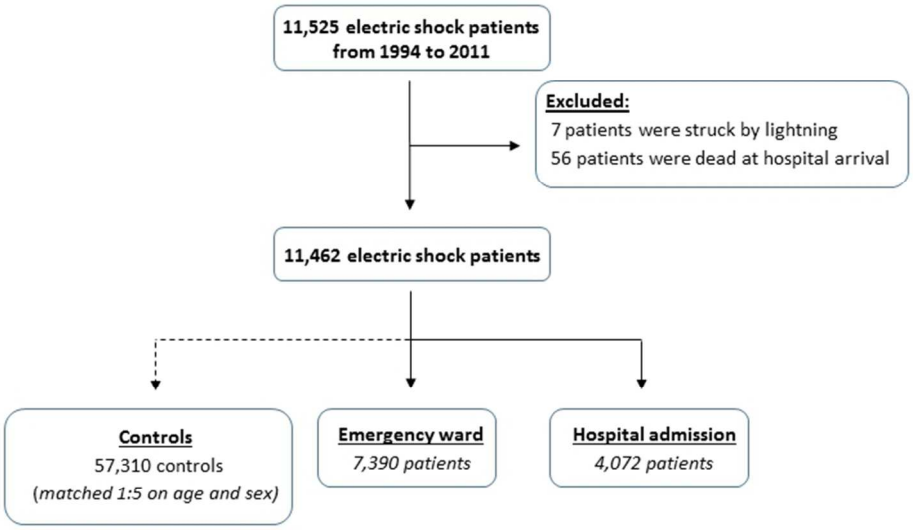
Supraventricular tachycardia	18 (0.0)	5 (0.1)	≤3 (≤0.1)	0.26
Ventricular tachycardia/fibrillation	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
Atrial fibrillation/flutter	26 (0.0)	4 (0.1)	5 (0.1)	0.10
Heart failure	20 (0.0)	5 (0.1)	6 (0.1)	<0.01

All results are reported as the number of patients (%) unless otherwise specified.

AMI, Acute myocardial infarction; AV, atrio-ventricular;

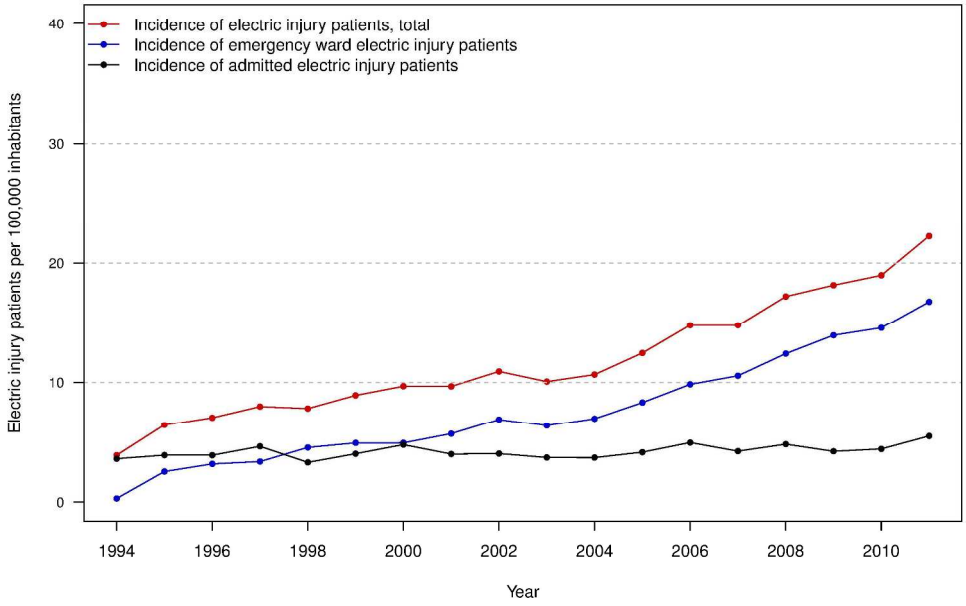
Patient numbers lower than 4 have been censored to ensure patient anonymity.

* The matched controls to admitted and emergency ward electric shock patients have been pooled in one group.



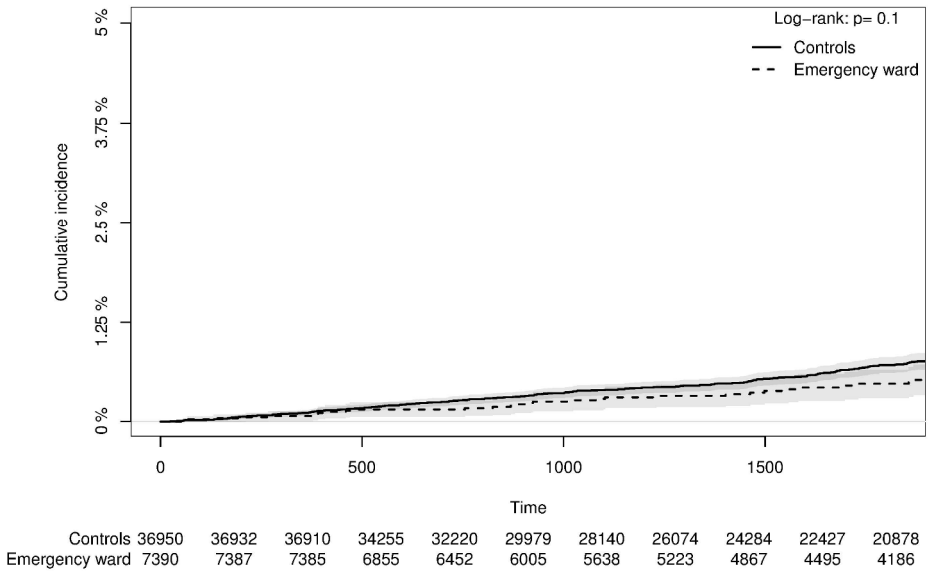
Selection process of the study population

205x126mm (96 x 96 DPI)



Incidence of electric shock patients per 100,000 Danish inhabitants from 1994 to 2011
Legend: The incidence of electric shock patients per 100,000 Danish inhabitants during the study period from 1994 to 2011.

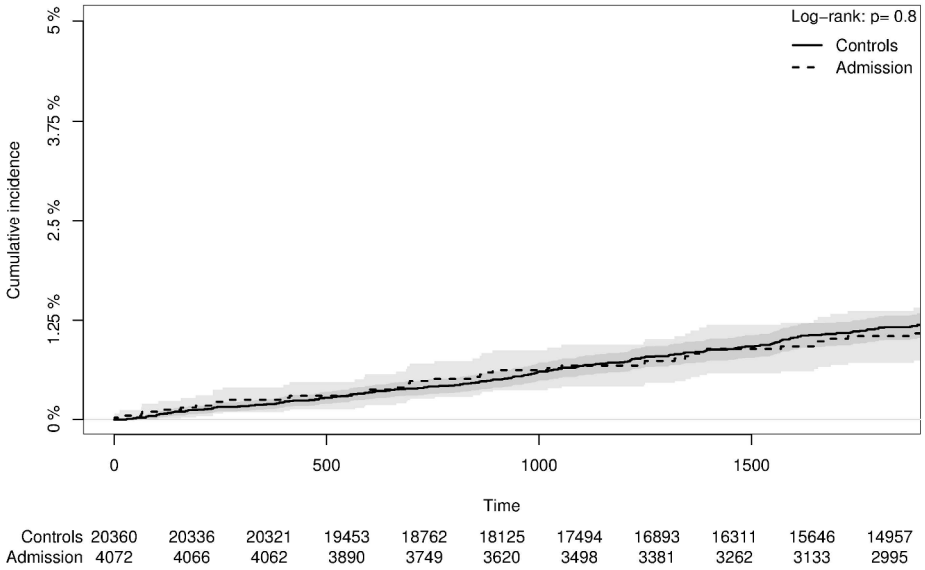
254x177mm (300 x 300 DPI)



Mortality following electric shock for emergency ward and admitted patients

Legend: Cumulative incidence of death for electric shock patients discharged from the emergency ward (N=7,390) and admitted to a hospital (N=4,071). Each patient in the two patient groups were matched with five controls (age and sex) randomly identified from the Danish population. The controls were followed from the day the corresponding case was exposed to the electric shock. 3A shows the cumulative incidence of death for emergency ward patients compared with matched controls. 3B shows the cumulative incidence of death for admitted patients compared with matched controls.

254x177mm (300 x 300 DPI)



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Supplementary material

Page 2-3 - Detailed list of ICD10 and procedure codes used to define comorbidities, cardiac diseases and cardiac procedures.

Page 4 – Patient case files

Detailed list of ICD-8, ICD-10, and procedure codes used to define comorbidities, cardiac diseases and cardiac procedures.

Table S1: ICD-8 and ICD-10 codes used to define comorbidities at baseline

Disease	ICD-8 (before 1994)	ICD-10 (After 1993)	Years before baseline
Ischemic heart disease (MI not included)	411-414	I20, I23, I24, I25	10
Cerebrovascular disease	430-438	I60-I69	10
Perifer vascular disease	440, 441, 443, 444, 445	I70-I74, R02	10
Previous AMI	410	I21	10
Pericarditis	420	I30, I31	10
Myocarditis	422	I40	10
Cardiomyopathy	425	I42	10
AV-block	4273	I44, I440, I441, I442, I443	10
Sick sinus syndrome		I495	10
Supraventricular tachycardia	4275	I471	10
Ventricular tachycardia/fibrillation	4276	I472, I490	10
Atrial fibrillation/flutter	4274	I48	10
Heart failure	4270, 4271, 428	I50	10

Table S2: Procedure codes to define previous procedures at basesline and procedures after electric shock

Procedure	Code (data available from 1996)
Pacemaker	BFCA0, BFCA01, BFCA02, BFCA03, BFCA04, BFCA05, BFCA06, BFCA07, BFCA09
ICD	BFCB0, BFCB00, BFCB01, BFCB02, BFCB03
Radiofrequency ablation	BFFB
CABG	KFNG00, KFNG02, KFNG05, KFNG10, KFNG12
PCI	KFNA, KFNB, KFNC, KFND, KFNE

Table S3: ICD-10 codes used to define cardiac diseases following electric shock

Disease	ICD-10 code
AMI	I21
Pericarditis	I30, I31
Myocarditis	I40
Cardiomyopathy	I42
AV-block	I44, I440, I441, I442, I443
Sick sinus syndrome	I495
Supraventricular tachycardia	I471
Ventricular tachycardia/fibrillation	I472, I490
Atrial fibrillation/flutter	I48
Heart failure	I50

Patient case files

According to Danish law, we applied The Danish Health Authority to review the case files of selected electric shock patients who had a new cardiac disease or cardiac procedure following the electric shock to evaluate whether the electric shock was considered responsible for the cardiac disease or procedure. Access to review the selected patient case files was approved by the Danish Health Authority (case no. 3-3013-1054/1/). In addition, the study was approved by the Danish Data Protection Agency (j.nr. 2007-58-0015/locale j.nr. GEH-2014-013, I-Suite nr: 02731). Ethical approval is not required for retrospective registry-based studies in Denmark.

The authority to obtain the patient case file data was restricted so the study investigators had to contact the Danish hospitals and hospital departments at which each patient was originally treated. Accordingly, data access was achieved in collaboration with responsible health care providers. The results presented in this study based on the case file reviews do not contain such detail that each patient can be identified.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Report numbers of outcome events or summary measures over time
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Other analyses	✓	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Results - Patient case file review
Discussion			
Key results	✓	18	Summarise key results with reference to study objectives Discussion
Limitations	✓	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Discussion
Interpretation	✓	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence ~ 1/2 + conclusion
Generalisability	✓	21	Discuss the generalisability (external validity) of the study results ~ 1 in
Other information			
Funding	✓	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based Funding after main text

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Mortality and Risk of Cardiac Complications Among Immediate Survivors of Accidental Electric Shock: A Danish Nationwide Cohort Study

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Keywords:	electric shock, electric injury, delayed arrhythmia, cardiac disease

Mortality and Risk of Cardiac Complications Among Immediate Survivors of Accidental Electric Shock: A Danish Nationwide Cohort Study

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Abstract

Objective: Exposure to electric shock has been associated with an increased risk of developing delayed cardiac arrhythmias and cardiac diseases. We examined whether electric shock patients have an increased risk of developing cardiac disease, cardiac arrhythmias, or death compared to the general Danish population.

Design: Matched cohort study.

Setting: A nationwide study in Denmark from 1994 to 2011.

Participants: We identified 11,462 Danish patients who visited an emergency ward or were admitted to a hospital due to electric shock from 1994 to 2011. Each patient was matched for age and sex with five random controls from the Danish population.

Main outcome measures: Mortality, cardiac procedures, and cardiac diseases following electric shock.

Results: A total of 7,390 electric shock patients were seen at the emergency ward and 4,072 electric shock patients were admitted to a hospital. The median patient age was 28.6 years (Q1-Q3, 21.3 to 37.7) in the emergency ward and 26.4 years (Q1-Q3, 18.3 to 37.4) for admitted patients. In both groups, most patients were male (74.0% and 76.8%). Few of the electric shock patients had a record of cardiovascular disease at baseline (364/11,462, 3.2%). The 5-year cumulative incidence of death was 0.47% (95% CI 0.29% to 0.65%) for emergency ward patients and 1.04% (95% CI 0.71% to 1.37%) for admitted patients. No difference in 5-year survival was observed compared to matched controls (emergency ward, p=0.10; admitted patients, p=0.80). Less than four patients received a pacemaker within 30 days.

Conclusions: This nationwide study did not demonstrate an increase in mortality among patients seen at hospitals after accidental electric shock compared with a background population. Cardiac procedures and diseases following electric shock were very rare. We suggest that nearly all patients can be discharged safely from the emergency room after electric shock without further observation.

Keywords: electric shock, electric injury, delayed arrhythmia, cardiac disease

Strengths and limitations of this study:

- A nationwide matched cohort study comparing electric shock patients to the general Danish population.
- Nationwide administrative registries were used to assess comorbidities, patient characteristics, and outcomes.
- Case files were reviewed for patients with electric shock who had a cardiac procedure or cardiac complication within 30 days following the electric shock to evaluate whether the complication was related to the electric shock.
- Information about the clinical evaluation that resulted in hospital admission or discharge from the emergency department was not available, including voltage exposure.

Introduction

Electric shock can cause immediate respiratory and cardiac arrest.[1,2] An increased risk of delayed arrhythmias has also been reported for clinical cases of electric shock,[3–6] and electrical shock has been associated with the development of heart failure[7], cardiomyopathy[8] and myocardial infarction.[9–11] Consequently, a variety of recommendations and clinical approaches have been suggested, and patients with identified risk factors, such as syncope, ECG changes, or high-voltage shock, are usually hospitalized for 24-48 hours for cardiac monitoring.[2,12–17] However, the incidence of late serious arrhythmias and cardiac complications has been difficult to document in both small prospective[12,18] and retrospective cohort studies.[19–21] Little is known about the long-term consequences for survivors who arrive at emergency wards or are admitted for observation. As such, current clinical practice is not based on evidence and the admission of multiple patients after electric shock is a strain for the patients, employers, and health care system.[17,22]

In the present study, we identified all Danish patients who visited an emergency ward or were admitted to a hospital due to electric shock over a period of 18 years to examine whether late arrhythmias had occurred and whether the exposed patients had an increased risk of developing cardiac disease or death compared to matched controls from the general Danish population.

Method

Study design and population

We performed a nationwide matched cohort study with patients in Denmark who received a diagnosis of electric shock (ICD-10 codes: DT754, DT754A, DW85, DW86, DW87) from an emergency ward, hospital admission, or as a cause of death between 1994 and 2011. We excluded patients exposed to lightning and patients who were dead upon arrival at the hospital following the electric shock. The study cases were followed from the day of the electric shock until death or 31 December 2012. If a patient had more than one electric shock, only the first was considered in this study. Each study case was matched for age and sex with five individuals randomly chosen from the Danish population. Matched controls were alive the same month as the associated case was exposed to the electric shock and followed from the day the associated case was exposed to the electric shock.

Patient characteristics at baseline

Data on age, sex, and vital status were obtained from the Danish Civil Registration System. Admission dates, discharge dates, and discharge diagnoses were gathered from the Danish National Patient Registry. Information on causes of death were collected from the Danish Register of Causes of Death. Cardiac diagnoses and procedures were obtained from the National Patient Register. Diagnoses were available from 1977. An ICD-8 classification was used until 1994, after which ICD-10 was used. Cardiac procedures were available from 1996. Based on this information, we identified any diseases or cardiac procedures until 10 years before the start of follow-up as baseline information. Supplementary table 1 contains details on the specific ICD-8/ICD-10 codes and procedure codes used to define comorbidities or prior procedures at baseline before the electric shock.

Study outcomes

The primary outcome was 5-year mortality for cases and controls. Secondary outcomes were the number of exposed patients who underwent a cardiac procedure or received a diagnosis of a new cardiac disease or arrhythmia within 30 days and 31 to 365 days after the electric shock compared to controls.

Cardiac complications and procedures after electric shock

Procedures included newly implanted pacemakers and temporary pacemakers (procedure codes “BFCA0”, ”BFCA01”, “BFCA02”, “BFCA03”, “BFCA04”, “BFCA05”, “BFCA06”, “BFCA07”,”BFCA9”) or newly implanted cardioverter defibrillators (procedure codes “BFCB0”, “BFCB00”, “BFCB01”, “BFCB02”, “BFCB03”); all radiofrequency ablation (RFA) procedures (“BFFB”); all cardiac revascularization treatments, including percutaneous coronary interventions (“KFNG00”, “KFNG02”, “KFNG05”, “KFNG10”, “KFNG12”); and coronary artery bypass grafting (CABG) (“KFNA”, “KFNB”, “KFNC”, “KFND”, “KFNE”).

Cardiac complications were identified using ICD-10 diagnosis codes. These comprised acute myocardial infarction (“I21”), pericarditis and other pericardial diseases (“I30”, “I31”), acute myocarditis (“I40”), cardiomyopathy (“I42), atrio-ventricular (AV) block (“I44.0”, ”I44.1”, “I44.2”, “I44.3”), bundle branch block (“I44.4”, “I44.5”, “I44.6”, “I44.7”, “I45.0”, “I45.1”, “I45.2”, “I45.3”, “I45.4”), sick sinus syndrome (“I49.5”), supraventricular tachycardia (“I47.1”), ventricular tachycardia (VT) (“I47.2”), ventricular fibrillation (VF) (“I49.0”), atrial fibrillation/atrial flutter (“I48”), and heart failure (“I50”).

Results with patient numbers < 4 were censored to ensure patient anonymity.

Patient case files

We obtained and reviewed case files related to the electric shock for 15 of the 23 patients (65%) who had a cardiac procedure or cardiac complication within 30 days following the electric shock (supplementary material).

Statistical analysis

We divided the electric shock patients in two groups: patients discharged directly from the emergency ward without any further observation and patients hospitalized and observed following the electric shock. Emergency ward patients were considered to be at low risk of cardiac complication, whereas admitted patients were considered to be at high risk of cardiac complications.

Continuous variables were reported as medians and 1st to 3rd quartiles (Q1-Q3). Continuous variables were compared using the Kruskal-Wallis rank sum test. Event numbers were compared between the controls, emergency ward patients, and admitted patients using the chi square test or Fisher's exact test. The incidence of electric shock patients was calculated as the number of electric shock patients per 100,000 Danish inhabitants each year. The incidence 95% confidence intervals (CIs) were calculated. Negative binomial regression was used to estimate temporal trends in incidences during the study period. Kaplan-Meier estimates were used to construct curves for the cumulative incidence of death. Two-sided p-values were reported.

Analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC) and R version 3.3.0.[23]

Ethics

The study was approved by the Danish Data Protection Agency (j.nr.: 2007-58-0015, internal reference GEH-2014-013, I-Suite nr.: 02731). Ethical approval is not required for retrospective registry-based studies in Denmark.

Allowance to identify and review the patient case files for the selected patients who experienced a procedure or cardiac complication was obtained from the Danish Health Authorities according to Danish law (case ref. 3-3013-1054/1/). Further information is available in the supplementary material.

Patient involvement

The study idea was conceived based on several patient contacts in emergency departments who had been exposed to electric shock and were admitted for observation. In addition, several of the exposed patients expressed concerns about whether they had an increased risk of developing cardiac diseases following the electric shock. No specific patients were involved in setting the research question or in the study design, interpretation of the results, or writing the manuscript.

Results

The study population consisted of 11,462 patients, 7,390 patients in the emergency ward group and 4,072 patients in the admission group. The selection process is shown in figure 1 and the baseline demographic characteristics of the patients and controls are given in table 1. The majority of the patients in both groups were male. Overall, few of the study patients had a record of cardiovascular disease at baseline (364/11,462, 3.2%). However, there was a tendency for admitted patients to have a greater prevalence of cardiac disease at baseline compared to controls. The length of hospital admission was ≤ 1 day for 3,888 (95.5%) of the admitted patients. Of the patients admitted, 190 (4.7%) were registered as having a burn injury. The incidence of electric shock patients increased from 3.9 per 100,000 persons (95% CI 3.4 to 4.5) in 1994 to 22.2 (95% CI 21.4 to 23.5) in 2011 (p<0.01). The increase was due primarily to an increase in patients seen at emergency departments from 1994 (0.3 per 100,000 persons, 95% CI 0.2 to 0.5) to 2011 (16.8 per 100,000 persons, 95% CI 15.7 to 17.9, p<0.01), whereas the number of patients admitted increased less during the study period (1994: 3.3 per 100,000 persons, 95% CI 3.1 to 4.1; 2011: 5.5 per 100,000 persons, 95% CI 5.2 to 5.8; p<0.01; figure 2).

The 5-year cumulative incidence of death was 0.47% (95% CI 0.29% to 0.65%) for emergency ward patients and 1.04% (95% CI 0.71% to 1.37%) for admitted patients. Figure 3 shows the 5-year cumulative incidence of death curves for the emergency ward and admitted patients compared to their matched controls. The overall mortality was low, and no difference was found between the emergency ward patients and admitted patients compared to the matched controls (p=0.10 and p=0.80, respectively).

Cardiac diseases and procedures

Table 2 illustrates the total number of cardiac procedures within 30 days and within 31-365 days after the electric shock. Within 30 days, fewer than four patients received a pacemaker. Overall, cardiac procedures were rare in the study population even 1 year after exposure to electric shock.

Table 3 shows new cardiac diseases for cases and controls within 30 days and within 31-365 days after the electric shock. Overall, new cardiac diseases among emergency ward and admitted patients were rare. The median age of the electric shock patients with atrial fibrillation within 30 days was 55.7 years (50.2 to 56.2). From 31 to 365 days after exposure, only heart failure, pericarditis, and VT/VF were different between the three study groups. For the 11 electric shock patients with a diagnosis of heart failure within 31 to 365 days after exposure, 6 (54.5%) had a record of ischemic heart disease or myocardial infarction.

Patient case file reviews

We were able to review case files for 15 patients who had a cardiac procedure or were registered as having cardiomyopathy, AV block, sick sinus syndrome, VT/VF, or heart failure within 30 days after the electric shock. In 3 (20%) files, the case description was not detailed enough to come to a conclusion about the relationship between the shock and subsequent cardiac procedure, arrhythmia, or cardiac disease. For the implanted pacemakers, none were related to the index electric shock. All of the cardiomyopathies identified in relation to the electric shock were of familiar or hypertrophic origin and not related to the electric shock. All reviewed heart failure cases were related to previously unidentified ischemic heart disease. For patients with VT or VF, the arrhythmia occurred in direct relation to the electric shock and not as a delayed arrhythmia. All of the VT/VF patients were resuscitated before hospital arrival. None of the sick sinus syndrome or AV block diseases were considered a consequence of the electric shock. The above description has omitted detailed descriptions of the patient cases to ensure patient anonymity (see supplementary material).

Discussion

This large nationwide cohort study did not identify excess mortality in patients exposed to electric shock compared to age- and sex-matched controls from the general population. This includes both patients who were admitted to a hospital and patients who were directly discharged from the emergency ward following the electric shock. Although rare, we found a marginally increased risk of cardiac arrhythmias, heart failure, and cardiomyopathy in patients who were hospitalized, most likely due to observation bias.

Several case reports have suggested a risk of delayed cardiac complications following an electric shock among patients who initially survived the electric shock. Jensen et al.[3] described three patients who developed VT and/or VF with a delay after exposure to electric shock of both high and low voltage. Cardiac biopsies revealed fibrosis in the myocardium of these three patients. Other case reports have reported sick sinus syndrome occurring long after the exposure to electric shock,[4] as well as atrial fibrillation[6,24] and bundle branch block.[13] Heart failure, cardiomyopathy, and myocardial infarction have also been reported as complications following electric shock.[7,8,11] Both myocardial damage and isolated damage to the electrophysiological system of the heart have been suggested as explanations for the proposed higher risk of arrhythmia and heart failure following an electric shock.[5,15,25] In addition, elevated CK-MB and electrocardiogram abnormalities have been reported to be frequent among electric shock patients in a Chinese study.[26] This suggests that exposure to electric shock may cause myocardial injury, hypothetically resulting in a higher mortality and morbidity among patients exposed to electric shock. However, this large study did not demonstrate any increased mortality for patients exposed to electric shock compared to the general population.

Several studies, both prospective and retrospective, have evaluated the risk of delayed arrhythmias and cardiac morbidity among patients exposed to electric shock. A recent study by Pawlik et al.[21] found no serious late dysrhythmias, and all study patients survived. Searle et al.[20] also found no serious delayed cardiac arrhythmias in a retrospective study of 268 patients admitted with electric injuries. Arrowsmith et al.[27] performed a retrospective study of 145 admitted patients, four of which had minor cardiac abnormalities, all present at the time of admission to the hospital. Bailey et al.[18] studied the occurrence of late arrhythmias among 134 patients considered at high risk of cardiac complications. No patients developed potentially lethal late arrhythmias. Purdue et al.[14] retrospectively considered 48 admitted patients exposed to high-voltage (>1000 V) shock and followed 10 patients prospectively after exposure to high voltage. Two of the patients had myocardial infarction at the time of admission. No serious late arrhythmias occurred during observation. Blackwell et al.[12] prospectively considered the need for cardiac monitoring following electric shock in 186 patients (196 presentations) using a standardized protocol. No serious delayed arrhythmias were observed. Cunningham et al.[13] found no delayed arrhythmias in a retrospective study of 70 admissions following electric shock. Thus, showing an increased risk of delayed arrhythmias among electric shock patients has been difficult. However, the previous studies were relatively small in size. In our study, arrhythmias and cardiac diseases following the electric shock were very rare. Among the case files we reviewed, the cardiac diseases were unlikely to be because of the electric shock, as they were chronic in nature and not identified prior to the clinical evaluation related to the electric shock. Among the patients with an AV block, none of the reviewed case files resulted in a pacemaker as a consequence of the electric shock. Atrial fibrillation/atrial flutter was more frequent among the electric shock patients than the control group. However, these patients had a higher median age than the rest of the electric shock patients. The risk of atrial fibrillation and undiagnosed silent atrial fibrillation increases with age.[28,29] Some of our study patients with atrial fibrillation may have had previously undetected atrial fibrillation because of the clinical examination following the electric shock. Furthermore, our study showed that, during the longer follow-up from 31 days to 365 days, the frequencies of cardiac diseases including atrial fibrillation/atrial flutter were similar when comparing the electric shock patients to the controls, except for heart failure. However, most of the heart failure patients (54.5%) had a history of ischemic heart disease or myocardial infarction.

Cases of VT and VF within 30 days occurred almost entirely in the admission group. In all of the reviewed case files, the VT/VF occurred in direct relation to the electric shock and not as a delayed arrhythmia. Consequently, we did not identify any patients with VT/VF occurring as a delayed arrhythmia after the electric shock.

Within 30 days after exposure, few patients in the admission group received a pacemaker. Patient case file reviews revealed that none of the cases could be related to the electric shock. In addition, the frequency of pacemaker procedures in the patients exposed to electric shock did not differ from the frequency in the control group 31 to 365 days following the electric shock.

We observed an increase in electric shock patients during the study period. The increase was mostly due to more electric shock patients being seen at emergency departments, whereas the number of admitted electric shock patients did not increase as much. We think this is related to a progressively lower threshold before going to the emergency department for clinical evaluation after low-risk electric shock.

Overall, our study cannot exclude a very small risk of delayed cardiac complications due to electric shock, but a likely explanation is observer bias because the electric shock patients were subject to a number of examinations that the control group was not. The fact that the observed arrhythmias were not associated with a significant effect on mortality and number of cardiac procedures, despite the large sample size, makes such an interpretation likely. In addition, this explanation seems likely based on the case file reviews.

The findings imply that patients exposed to electric shock can be discharged safely from the emergency ward unless there is an obvious cardiac injury, cardiac arrhythmia, suggestion of an underlying previously undetected cardiac disease, or traumatic injury that requires immediate treatment.

Limitations

A limitation of the present study is the observational design, which does not allow an evaluation of the causal relationship between the complications and electric shock. Importantly, mortality and cardiac complications were rare, supporting our conclusions that almost all patients without immediate cardiac complications or trauma are unlikely to suddenly die or develop a delayed cardiac disease because of the electric shock.

The number of electric shock incidents likely underestimates the total number of electric shock incidents in Denmark during the study period because many victims are evaluated in the primary care health system without referral for secondary care evaluation, or they never make contact with the health care system. However, any complications following electric shock in the general population would most likely have occurred in our study population, as these patients were selected for further observation during a hospital admission or at the emergency ward.

We were unable to obtain all of the patient case files. However, the ones we successfully evaluated did not demonstrate an increased risk of delayed arrhythmias or cardiac diseases following electric shock. In

addition, information about the clinical evaluation that resulted in a hospital admission or discharge from the emergency department was not available, including voltage exposure. However, the scope of this study was to evaluate the risk of mortality and cardiac complications following an electric shock based on an initial clinical evaluation and whether the patient needed observation and monitoring following the electric shock. Furthermore, previous studies reported delayed cardiac arrhythmias following both low- and high-voltage electric injuries.[3,30,17]

This study was conducted in a Western, developed country and the results may not apply to developing countries.

Conclusion

This large nationwide study did not demonstrate an increase in mortality among patients seen at hospitals after accidental electric shock compared to a matched background population. Furthermore, cardiac procedures and diseases following electric shock were very rare. We suggest that observer bias can explain these observations and that nearly all patients can be discharged safely from the emergency room after accidental electric shock without further observation.

Acknowledgements

None

Competing interests statement

All authors have completed the ICMJE uniform disclosure form.

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Author Contributions

The study was conceived by Steen Hansen, Christian Torp-Pedersen, Sam Riahi, and Søren Hjortshøj. Most analyses were performed by Steen Hansen with support from Rikke Mortensen. The initial manuscript draft was written by Steen Hansen. Christian Torp-Pedersen, Sam Riahi, Søren Hjortshøj, Lars Køber, Rikke Mortensen, and Peter Søgaard contributed to the interpretation of the data and critical revisions of the manuscript. Steen Hansen, Christian Torp-Pedersen, Sam Riahi, Søren Hjortshøj, Lars Køber, Rikke Mortensen, and Peter Søgaard have approved the final version of the manuscript.

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Figures

Figure 1

Selection process for the study population.

Figure 2

Incidence of electric shock patients per 100,000 Danish inhabitants from 1994 to 2011.

Figure 3

Mortality following electric shock for emergency ward and admitted patients. (A) Cumulative incidence of death for electric shock patients discharged from the emergency ward (N=7,390) or (B) admitted to a hospital (N=4,071). Each patient was age- and sex-matched with five controls randomly identified from the Danish population. The controls were followed from the day the corresponding case was exposed to the electric shock.

Tables

Table 1: Baseline characteristics of electric shock patients and controls from the Danish population with comorbidities and prior cardiac procedures before the beginning of follow-up

Characteristic	Controls*	Emergency Ward Admission	P-value
N	57,310	7,390	4,072	
Median age, years (Q1, Q3)	28.0 (20.3, 37.7)	28.6 (21.3, 37.7)	26.4 (18.3, 37.4)	<0.01
Median follow-up, years (Q1, Q3)	6.7 (3.5, 11.5)	5.8 (3.1, 10.1)	9.1 (4.8, 13.8)	<0.01
Gender, male	42,960 (75.0)	5,466 (74.0)	3,127 (76.8)	<0.01
Ischemic heart disease (MI not included)	412 (0.7)	99 (1.3)	66 (1.6)	<0.01
Cerebrovascular disease	241 (0.4)	46 (0.6)	27 (0.7)	<0.01
Perifer vascular disease	102 (0.2)	12 (0.2)	9 (0.2)	0.77
Previous AMI	168 (0.3)	26 (0.4)	25 (0.6)	<0.01
Pericarditis	55 (0.1)	22 (0.3)	4 (0.1)	<0.01
Myocarditis	10 (0.0)	5 (0.1)	≤3 (≤0.1)	0.03
Cardiomyopathy	32 (0.1)	6 (0.1)	9 (0.2)	<0.01
AV block	22 (0.0)	6 (0.1)	7 (0.2)	<0.01
Sick sinus syndrome	16 (0.0)	4 (0.1)	6 (0.1)	<0.01
Supraventricular tachycardia	115 (0.2)	30 (0.4)	26 (0.6)	<0.01
Ventricular tachycardia/fibrillation	29 (0.1)	9 (0.1)	8 (0.2)	<0.01
Atrial fibrillation/flutter	180 (0.3)	29 (0.4)	14 (0.3)	0.52
Heart failure	92 (0.2)	11 (0.1)	16 (0.4)	<0.01
Pacemaker	14 (0.0)	8 (0.1)	5 (0.1)	<0.01
ICD	13 (0.0)	≤3 (0.0)	6 (0.1)	<0.01
Radiofrequency ablation	40 (0.1)	10 (0.1)	5 (0.1)	0.11
CABG	49 (0.1)	6 (0.1)	≤3 (≤0.1)	0.96
PCI	67 (0.1)	12 (0.2)	7 (0.2)	0.40

Data are reported as the number of patients (%) unless otherwise specified. Q1, Q3, 1st+3rd quartiles

AMI, acute myocardial infarction; AV, atrio-ventricular; ICD, implantable cardioverter defibrillator; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention

Patient numbers < 4 have been censored to ensure patient anonymity.

* The matched controls to admitted and emergency ward electric shock patients were pooled into one group.

Table 2: Cardiac procedures following electric shock

Characteristic	Controls*	Emergency Ward	Admission	P-value
N	57,310	7,390	4,072	
< 31 days after exposure				
Pacemaker	0 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
ICD	0	0	0	NA
Radiofrequency ablation	0	0	0	NA
CABG	0	0	0	NA
PCI	≤3 (0.0)	0 (0.0)	0 (0.0)	1
31-365 days after exposure				
Pacemaker	6 (0.0)	0 (0.0)	0 (0.0)	1
ICD	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	0.20
Radiofrequency ablation	≤3 (0.0)	≤3 (0.0)	≤3 (≤0.1)	<0.01
CABG	≤3 (0.0)	≤3 (0.0)	≤3 (≤0.1)	0.02
PCI	14 (0.0)	≤3 (0.0)	≤3 (≤0.1)	0.41

Data are reported as the number of patients (%) unless otherwise specified.

ICD, implantable cardioverter defibrillator; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.

Patient numbers < 4 have been censored to ensure patient anonymity.

* The matched controls to admitted and emergency ward electric shock patients were pooled into one group.

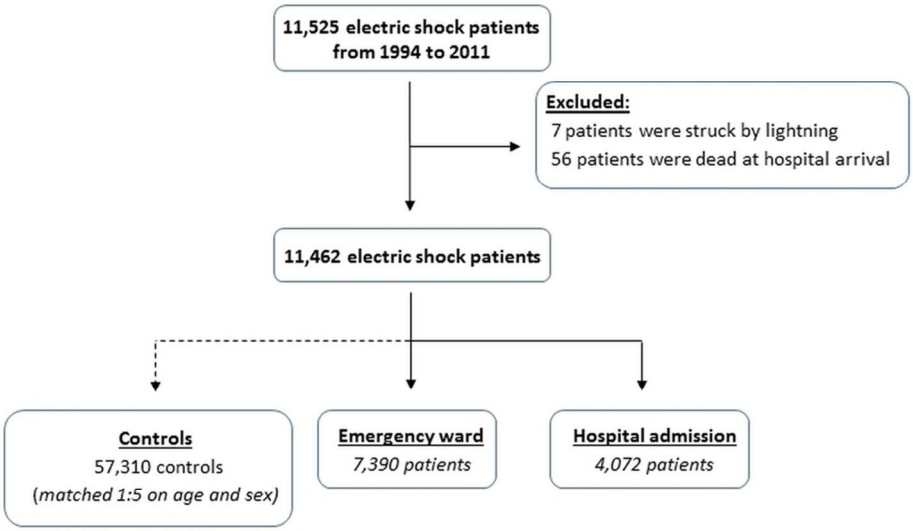
Table 3: Cardiac diseases following electric shock				
Characteristic	**Controls***	**Emergency Ward**	**Admission**	**P-value**
N	57,310	7,390	4,072	
< 31 days after exposure				
AMI	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	0.20
Pericarditis	0	0	0	NA
Myocarditis	0	0	0	NA
Cardiomyopathy	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
AV block	≤3 (0.0)	0 (0.0)	8 (0.2)	<0.01
Sick sinus syndrome	0 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
Supraventricular tachycardia	0 (0.0)	≤3 (0.0)	4 (0.1)	<0.01
Ventricular tachycardia/fibrillation	≤3 (0.0)	0 (0.0)	7 (0.2)	<0.01
Atrial fibrillation/flutter	≤3 (0.0)	≤3 (0.0)	12 (0.3)	<0.01
Heart failure	≤3 (0.0)	≤3 (0.0)	0 (0.0)	0.52
31-365 days after exposure				
AMI	24 (0.0)	≤3 (0.0)	5 (0.1)	0.09
Pericarditis	7 (0.0)	≤3 (0.0)	≤3 (≤0.1)	0.04
Myocarditis	≤3 (0.0)	0 (0.0)	0 (0.0)	1
Cardiomyopathy	9 (0.0)	0 (0.0)	≤3 (≤0.1)	0.14
AV block	4 (0.0)	0 (0.0)	≤3 (≤0.1)	0.09
Sick sinus syndrome	4 (0.0)	0 (0.0)	≤3 (≤0.1)	0.34
Supraventricular tachycardia	18 (0.0)	5 (0.1)	≤3 (≤0.1)	0.26
Ventricular tachycardia/fibrillation	≤3 (0.0)	0 (0.0)	≤3 (≤0.1)	<0.01
Atrial fibrillation/flutter	26 (0.0)	4 (0.1)	5 (0.1)	0.10
Heart failure	20 (0.0)	5 (0.1)	6 (0.1)	<0.01

Data are reported as the number of patients (%) unless otherwise specified.

AMI, acute myocardial infarction; AV, atrio-ventricular

Patient numbers < 4 have been censored to ensure patient anonymity.

* The matched controls to admitted and emergency ward electric shock patients were pooled into one group.



Selection process of the study population

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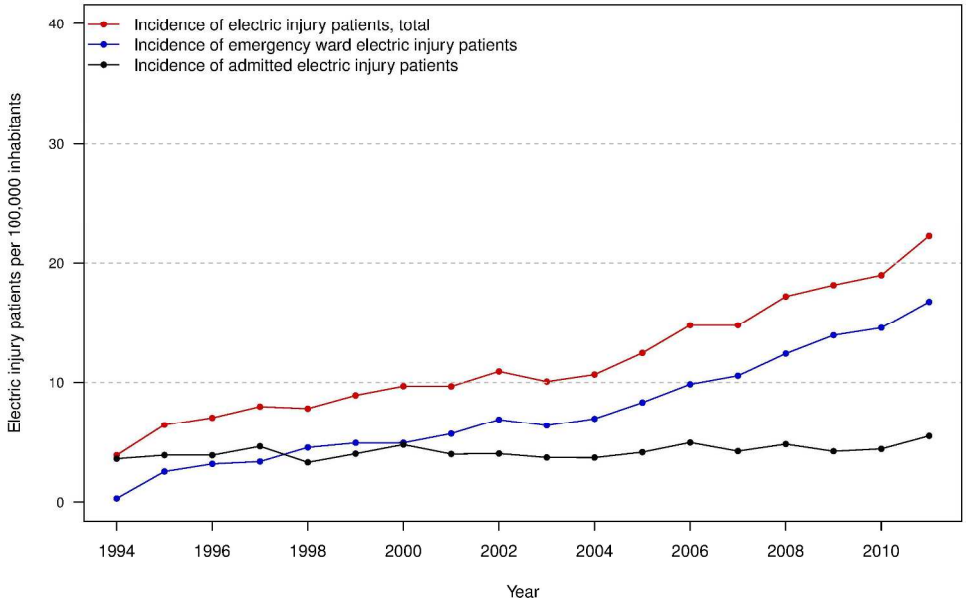

Incidence of electric shock patients per 100,000 Danish inhabitants from 1994 to 2011
Legend: The incidence of electric shock patients per 100,000 Danish inhabitants during the study period from 1994 to 2011.

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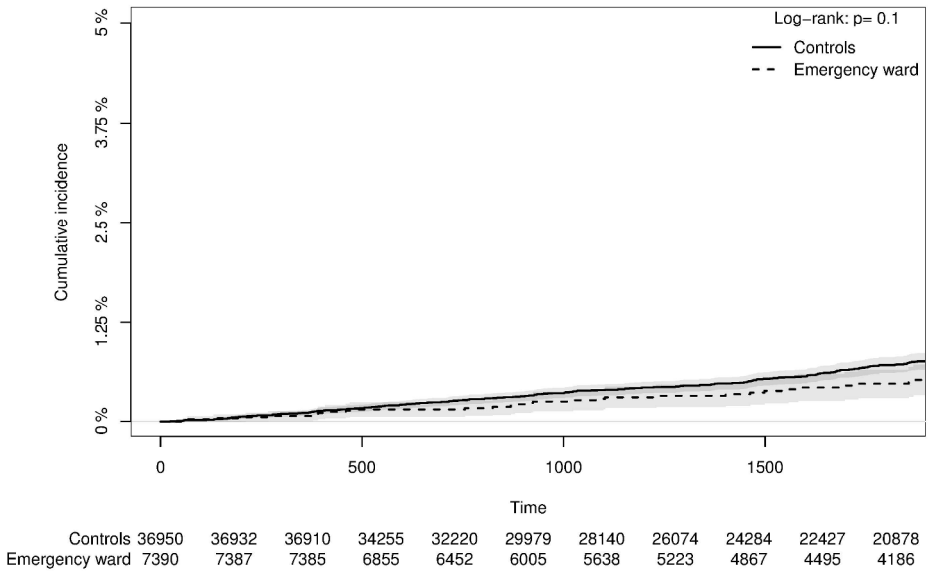

Mortality following electric shock for emergency ward and admitted patients

Legend: Cumulative incidence of death for electric shock patients discharged from the emergency ward (N=7,390) and admitted to a hospital (N=4,071). Each patient in the two patient groups were matched with five controls (age and sex) randomly identified from the Danish population. The controls were followed from the day the corresponding case was exposed to the electric shock. 3A shows the cumulative incidence of death for emergency ward patients compared with matched controls. 3B shows the cumulative incidence of death for admitted patients compared with matched controls.

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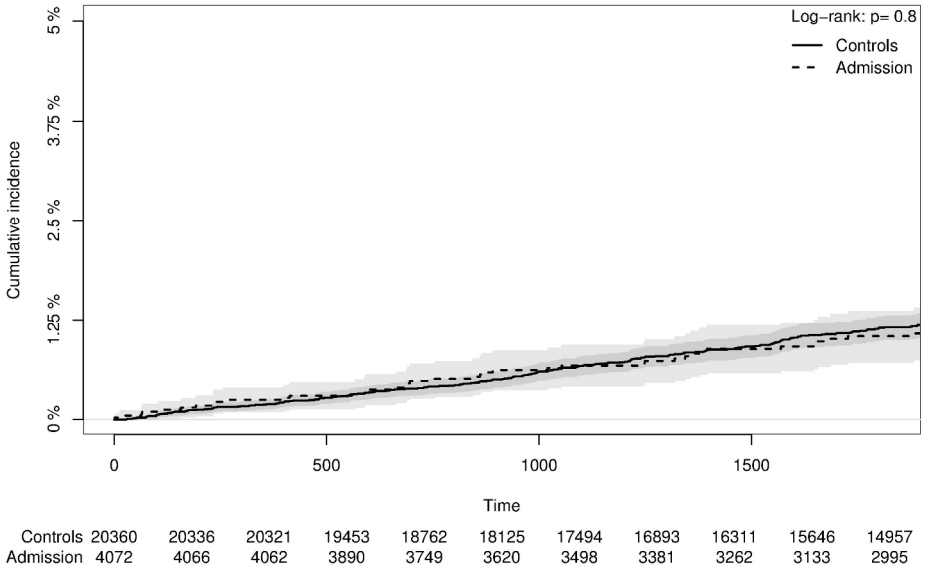

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Supplementary material

Page 2-3 - Detailed list of ICD10 and procedure codes used to define comorbidities, cardiac diseases and cardiac procedures.

Page 4 – Patient case files

Detailed list of ICD-8, ICD-10, and procedure codes used to define comorbidities, cardiac diseases and cardiac procedures.

Table S1: ICD-8 and ICD-10 codes used to define comorbidities at baseline			
Disease	**ICD-8 (before 1994)**	**ICD-10 (After 1993)**	**Years before baseline**
Ischemic heart disease (MI not included)	411-414	I20, I23, I24, I25	10
Cerebrovascular disease	430-438	I60-I69	10
Perifer vascular disease	440, 441, 443, 444, 445	I70-I74, R02	10
Previous AMI	410	I21	10
Pericarditis	420	I30, I31	10
Myocarditis	422	I40	10
Cardiomyopathy	425	I42	10
AV-block	4273	I44, I440, I441, I442, I443	10
Sick sinus syndrome		I495	10
Supraventricular tachycardia	4275	I471	10
Ventricular tachycardia/fibrillation	4276	I472, I490	10
Atrial fibrillation/flutter	4274	I48	10
Heart failure	4270, 4271, 428	I50	10

Table S2: Procedure codes to define previous procedures at basesline and procedures after electric shock	
Procedure	**Code (data available from 1996)**
Pacemaker	BFCA0, BFCA01, BFCA02, BFCA03, BFCA04, BFCA05, BFCA06, BFCA07, BFCA09
ICD	BFCB0, BFCB00, BFCB01, BFCB02, BFCB03
Radiofrequency ablation	BFFB
CABG	KFNG00, KFNG02, KFNG05, KFNG10, KFNG12
PCI	KFNA, KFNB, KFNC, KFND, KFNE

Table S3: ICD-10 codes used to define cardiac diseases following electric shock	
Disease	**ICD-10 code**
AMI	I21
Pericarditis	I30, I31
Myocarditis	I40
Cardiomyopathy	I42
AV-block	I44, I440, I441, I442, I443
Sick sinus syndrome	I495
Supraventricular tachycardia	I471
Ventricular tachycardia/fibrillation	I472, I490
Atrial fibrillation/flutter	I48
Heart failure	I50

Patient case files

According to Danish law, we applied The Danish Health Authority to review the case files of selected electric shock patients who had a new cardiac disease or cardiac procedure following the electric shock to evaluate whether the electric shock was considered responsible for the cardiac disease or procedure. Access to review the selected patient case files was approved by the Danish Health Authority (case no. 3-3013-1054/1/). In addition, the study was approved by the Danish Data Protection Agency (j.nr. 2007-58-0015/locale j.nr. GEH-2014-013, I-Suite nr: 02731). Ethical approval is not required for retrospective registry-based studies in Denmark.

The authority to obtain the patient case file data was restricted so the study investigators had to contact the Danish hospitals and hospital departments at which each patient was originally treated. Accordingly, data access was achieved in collaboration with responsible health care providers. The results presented in this study based on the case file reviews do not contain such detail that each patient can be identified.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	4+7 +fig 1
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	4-6
Study size	10	Explain how the study size was arrived at	4-6 + fig 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, explain how loss to follow-up was addressed	4-6
		(*e*) Describe any sensitivity analyses	6-5+ supplement
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	fig 1 7-8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1 & 7-8
		(b) Indicate number of participants with missing data for each variable of interest	-
		(c) Summarise follow-up time (eg, average and total amount)	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures over time	7-8 table 1-3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7-8

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.