

BMJ Open Mortality and risk of cardiac complications among immediate survivors of accidental electric shock: a Danish nationwide cohort study

Steen Møller Hansen,¹ Sam Riahi,² Søren Hjortshøj,² Rikke Mortensen,¹ Lars Køber,³ Peter Søgaard,² Christian Torp-Pedersen⁴

To cite: Hansen SM, Riahi S, Hjortshøj S, *et al.* Mortality and risk of cardiac complications among immediate survivors of accidental electric shock: a Danish nationwide cohort study. *BMJ Open* 2017;7:e015967. doi:10.1136/bmjopen-2017-015967

► Prepublication history and additional material are available. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2017-015967>).

Received 17 January 2017
Revised 7 June 2017
Accepted 4 July 2017



CrossMark

¹Department of Clinical Epidemiology, Aalborg University Hospital, Aalborg, Denmark

²Department of Cardiology, Aalborg University Hospital, Aalborg, Denmark

³Department of Cardiology, The Heart Centre, Rigshospitalet, Copenhagen University Hospital, Copenhagen, Denmark

⁴Department of Health Science and Technology, Aalborg University, Aalborg, Denmark

Correspondence to

Dr Steen Møller Hansen; steenmlerh@gmail.com

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 with 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 7390 electric shock patients were seen at an emergency ward and 4072 electric shock patients were admitted to a hospital. The median patient age was 28.6 years (Q1–Q3, 21.3–37.7) for the emergency ward patients and 26.4 years (Q1–Q3, 18.3–37.4) 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 with matched controls (emergency ward, $p=0.10$; admitted patients, $p=0.80$). Fewer 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.

INTRODUCTION

Electric shock can cause immediate respiratory and cardiac arrest.^{1 2} An increased risk of delayed arrhythmias has also been reported

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.

for clinical cases of electric shock,^{3–6} and electrical shock has been associated with the development of heart failure,⁷ cardiomyopathy⁸ 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 hospitalised 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 with 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 (International Statistical Classification of Diseases and Related Health Problems (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 on 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. The online 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 31–365 days after the electric shock compared with 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 revascularisation 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'), atrioventricular (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 (see online 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 hospitalised 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 first to third 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 χ^2 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% 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 V.9.4 (SAS Institute, Cary, North Carolina, USA) and R V.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

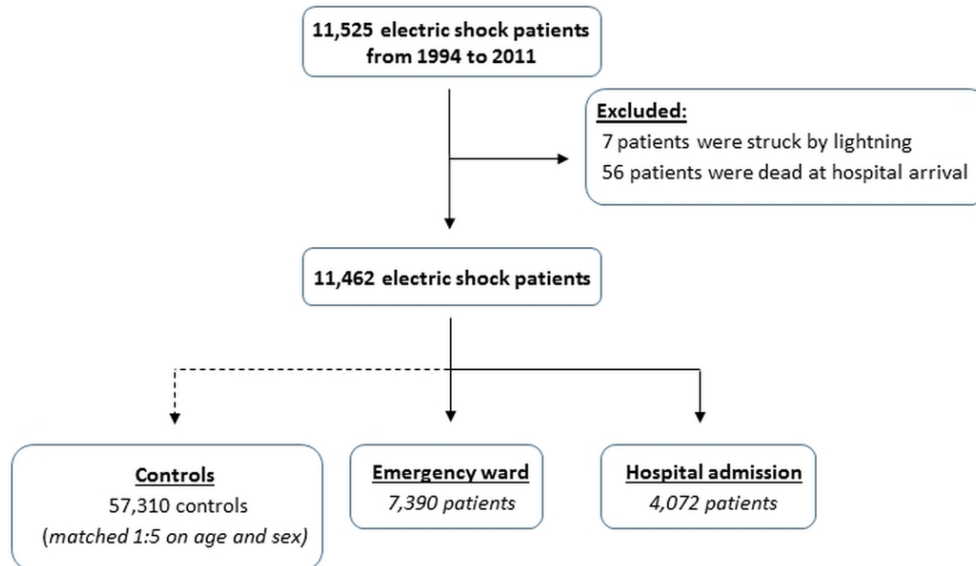


Figure 1 Selection process for the study population.

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 online 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, 7390 patients in the emergency ward group and 4072 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 with controls. The length of hospital admission was ≤ 1 day for 3888 (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 1 000 000 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 and 4](#) show the 5-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 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, 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 (50.2–56.2). 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 31–365 days after exposure, 6 (54.5%) had a record of ischaemic heart disease or myocardial infarction.

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

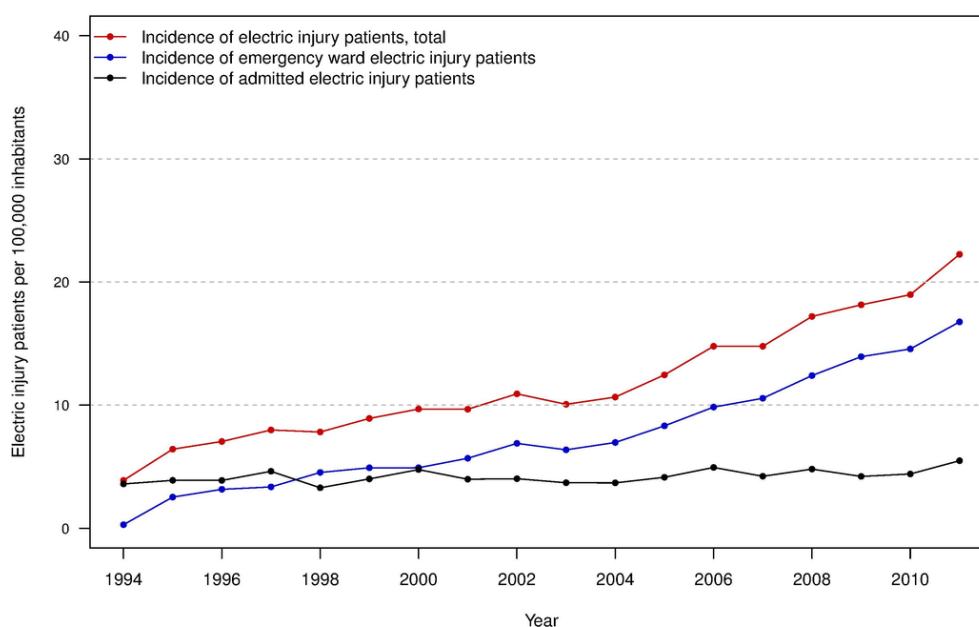
Characteristic	Controls*	Emergency ward	Admission	p Value
N	57310	7390	4072	
Median age, years (Q1, Q3)	28.0 (20.3, 37.7)	28.6 (21.3, 37.7)	26.4 (18.3, 37.4)	<0.01
Median follow-up, years (Q1, Q3)	6.7 (3.5, 11.5)	5.8 (3.1, 10.1)	9.1 (4.8, 13.8)	<0.01
Gender, male	42960 (75.0)	5466 (74.0)	3127 (76.8)	<0.01
Ischaemic 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
Peripheral 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, first+third quartiles.

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.

AMI, acute myocardial infarction; AV, atrioventricular; CABG, coronary artery bypass grafting; ICD, implantable cardioverter defibrillator; MI, myocardial infarction; PCI, percutaneous coronary intervention.

**Figure 2** The incidence of electric shock patients per 100 000 Danish inhabitants during the study period from 1994 to 2011.

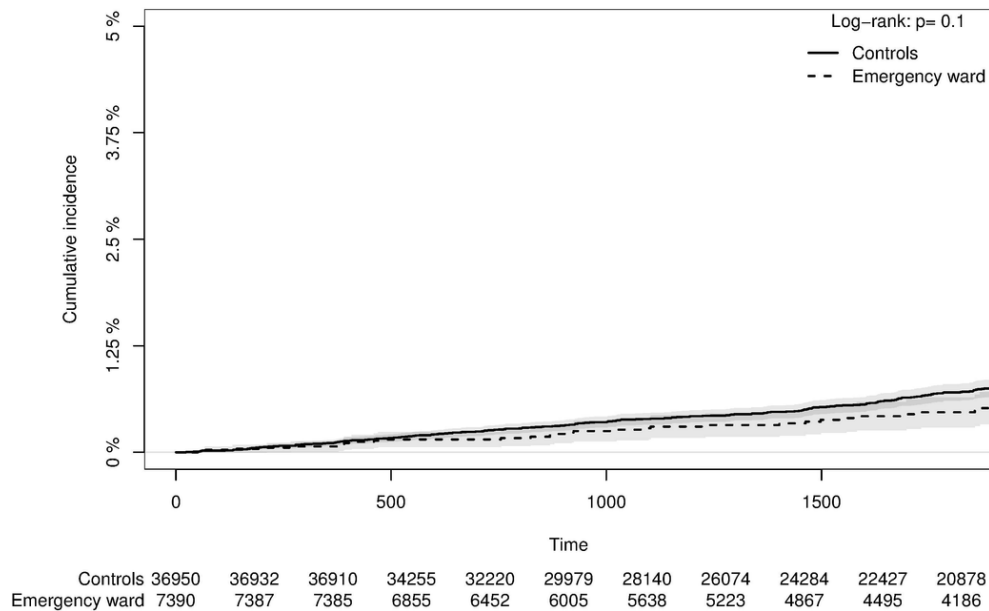


Figure 3 Mortality following electric shock for emergency ward. Cumulative incidence of death for electric shock patients discharged from the emergency ward (n=7390). Each patient was age-matched and sex-matched with five controls randomly identified from the Danish population. The controls were followed from the day the corresponding case was exposed to the electric shock.

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 three (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 was 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 ischaemic 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 the patients with VT/VF were resuscitated before hospital arrival. None of the sick sinus syndrome or AV block diseases was considered a consequence of the electric shock. The above description has omitted detailed descriptions of the patient cases to ensure patient anonymity (see online supplementary material).

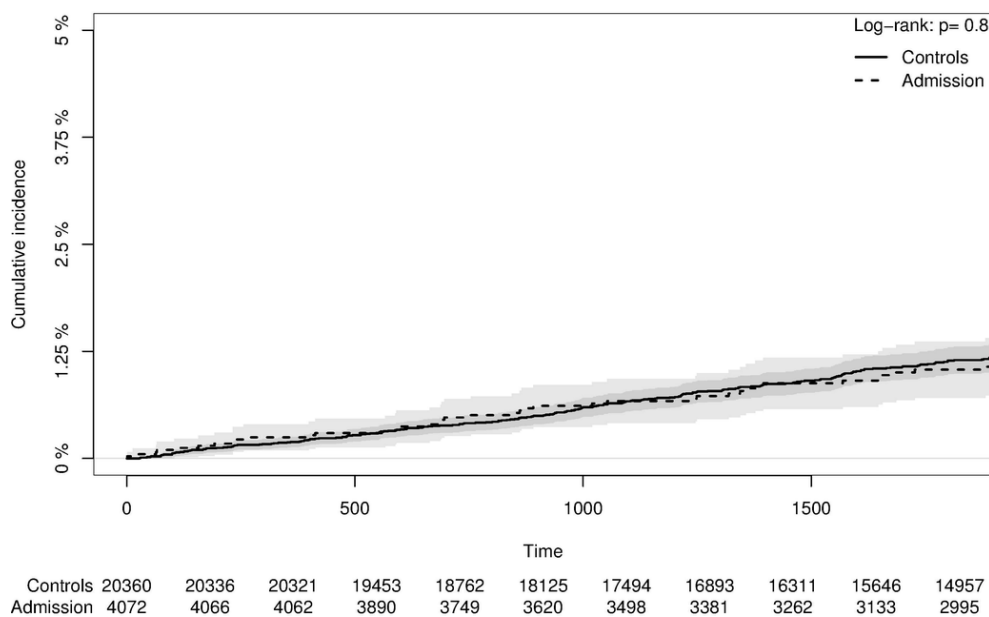


Figure 4 Mortality following electric shock for admitted patients. Cumulative incidence of death for electric shock patients admitted to a hospital (n=4072). Each patient was age-matched and sex-matched with five controls randomly identified from the Danish population. The controls were followed from the day the corresponding case was exposed to the electric shock.

Table 2 Cardiac procedures following electric shock

Characteristic	Controls*	Emergency ward	Admission	p Value
N	57 310	7390	4072	
<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.

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.

CABG, coronary artery bypass grafting; ICD, implantable cardioverter defibrillator; NA, not available; PCI, percutaneous coronary intervention.

DISCUSSION

This large nationwide cohort study did not identify excess mortality in patients exposed to electric shock compared with age- matched 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 hospitalised, 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 ECG 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 with 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, 4 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 and Hunt¹⁴ 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 and Haylar¹² prospectively considered the need for cardiac monitoring following electric shock in 186 patients (196 presentations) using a standardised protocol. No serious delayed arrhythmias were observed. Cunningham¹³ 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

Table 3 Cardiac diseases following electric shock

Characteristic	Controls*	Emergency ward	Admission	p Value
N	57 310	7390	4072	
<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.

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.

AMI, acute myocardial infarction; AV, atrioventricular; NA, not available.

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 with the controls, except for heart failure. However, most of the patients with heart failure (54.5%) had a history of ischaemic 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 healthcare 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-voltage and high-voltage electric injuries.^{3 17 30}

This study was conducted in a Western, high-income country and the results may not apply to middle-income countries.

Conclusion

This large nationwide study did not demonstrate an increase in mortality among patients seen at hospitals after accidental electric shock compared with 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.

Contributors The study was conceived by SMH, CT-P, SR and SØH. Most analyses were performed by SMH with support from RM. The initial manuscript draft was written by SMH. CT-P, SR, SØH, LK, RM and PSØ contributed in the interpretation of the data analyses and critical revisions of manuscript versions. SMH, CT-P, SR, SØH, LK, RM and PSØ have approved the final version of the manuscript.

Funding This research received no specific grant from any funding agency in the public, commercial or non-profit sectors.

Competing interests None declared.

Ethics approval 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.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data available.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2017. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

REFERENCES

- Hussmann J, Kucan JO, Russell RC, et al. Electrical injuries--morbidity, outcome and treatment rationale. *Burns* 1995;21:530-5.
- Maghsoudi H, Adyani Y, Ahmadian N. Electrical and lightning injuries. *J Burn Care Res* 2007;28:255-61.
- Jensen PJ, Thomsen PE, Bagger JP, et al. Electrical injury causing ventricular arrhythmias. *Br Heart J* 1987;57:279-83.
- Kose S, Ilysoy A, Kursaklioglu H, et al. Electrical injury as a possible cause of sick sinus syndrome. *J Korean Med Sci* 2003;18:114-5.
- Robinson NM, Chamberlain DA. Electrical injury to the heart may cause long-term damage to conducting tissue: a hypothesis and review of the literature. *Int J Cardiol* 1996;53:273-7.
- Akdemir R, Gunduz H, Erbilin E, et al. Atrial fibrillation after electrical shock: a case report and review. *Emerg Med J* 2004;21:744-6.
- Guinard JP, Chioloro R, Buchser E, et al. Myocardial injury after electrical burns: short and long term study. *Scand J Plast Reconstr Surg Hand Surg* 1987;21:301-2.
- Buono LM, DePace NL, Elbaum DM. Dilated cardiomyopathy after electrical injury: report of two cases. *J Am Osteopath Assoc* 2003;103:247-9.
- Ranjan A, Kulkarni S, Dalvi B. Myocardial infarction following electric shock. *Indian Heart J* 1997;49:179-80.
- Kozlova AP, Malinovsky ML. [Myocardial infarct following electric trauma]. *Ter Arkh* 1968;40:110-1.
- Kinney TJ. Myocardial infarction following electrical injury. *Ann Emerg Med* 1982;11:622-5.
- Blackwell N, Hayllar J. A three year prospective audit of 212 presentations to the emergency department after electrical injury with a management protocol. *Postgrad Med J* 2002;78:283-5.
- Cunningham PA. The need for cardiac monitoring after electrical injury. *Med J Aust* 1991;154:765-6.
- Purdue GF, Hunt JL. Electrocardiographic monitoring after electrical injury: necessity or luxury. *J Trauma* 1986;26:166-7.
- Amino M, Yoshioka K, Morita S, et al. Two cases in which myocardial injury could be only evaluated by nuclear medicine studies on electric shock patients whose electrocardiogram and myocardial enzyme levels were normal. *J Trauma* 2009;66:666-71.
- Carleton SC. Cardiac problems associated with electrical injury. *Cardiol Clin* 1995;13:263-6.
- Waldmann V, Narayanan K, Combes N, et al. Electrical cardiac injuries: current concepts and management. *Eur Heart J* 2017;1-8.
- Bailey B, Gaudreault P, Thivierge RL. Cardiac monitoring of high-risk patients after an electrical injury: a prospective multicentre study. *Emerg Med J* 2007;24:348-52.
- Celik A, Ergun O, Ozok G. Pediatric electrical injuries: a review of 38 consecutive patients. *J Pediatr Surg* 2004;39:1233-7.

20. Searle J, Slagman A, Maaß W, *et al.* Cardiac monitoring in patients with electrical injuries. An analysis of 268 patients at the Charité Hospital. *Dtsch Arztebl Int* 2013;110:847–53.
21. Pawlik AM, Lampart A, Stephan FP, *et al.* Outcomes of electrical injuries in the emergency department: a 10-year retrospective study. *Eur J Emerg Med* 2016;23:448–54.
22. Waldmann V, Narayanan K, Combes N, *et al.* Electrical injury. *BMJ* 2017;357:j1418–7.
23. R Core Team. R: a language and environment for Statistical Computing, 2015. <http://www.r-project.org> (accessed 24 May 2017).
24. Bøggild H, Freund L, Bagger JP. Persistent atrial fibrillation following electrical injury. *Occup Med* 1995;45:49–50.
25. Fineschi V, Di Donato S, Mondillo S, *et al.* Electric shock: Cardiac effects relative to non fatal injuries and post-mortem findings in fatal cases. *Int J Cardiol* 2006;111:6–11.
26. Sun CF, Lv XX, Li YJ, *et al.* Epidemiological studies of electrical injuries in Shaanxi province of China: a retrospective report of 383 cases. *Burns* 2012;38:568–72.
27. Arrowsmith J, Usgaocar RP, Dickson WA. Electrical injury and the frequency of cardiac complications. *Burns* 1997;23:576–8.
28. Lowres N, Neubeck L, Redfern J, *et al.* Screening to identify unknown atrial fibrillation. A systematic review. *Thromb Haemost* 2013;110:213–22.
29. Lloyd-Jones DM, Wang TJ, Leip EP, *et al.* Lifetime risk for development of atrial fibrillation: the framingham heart study. *Circulation* 2004;110:1042–6.
30. Arnoldo BD, Purdue GF, Kowalske K, *et al.* Electrical injuries: a 20-year review. *J Burn Care Rehabil* 2004;25:479–84.