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Cardiac monitoring in patients with electrocution injury

Elektrik çarpması yaralanması olan hastalarda kardiyak monitörizasyon

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BACKGROUND
The necessity of admitting patients exposed to electrocution injuries for monitoring and observation in the emergency department (ED) remains controversial.

METHODS
We evaluated the medical records of 102 patients (86 male, 16 female; median age 29.5; range 18 to 68 years) admitted to the adult ED with electrocution injuries over the past 20 years.

RESULTS
Only 9 deaths were reported: 3 as a result of contact with low-voltage electricity and 6 after contact with high-voltage electricity. With the exception of a case of sepsis, all deaths were related to early rhythm abnormalities immediately following the incident. The ECG findings of surviving patients in the study group were as follows: 70 normal, 8 sinus tachycardia, 3 sinus bradycardia, 4 ST-T wave changes, and 1 ventricular extrasystole. ECG recordings of 7 patients could not be found. 72 cases had been followed up with repeat ECG recordings. There were no observed ECG changes requiring any medical or electrical therapies in the surviving patients.

CONCLUSION
Cardiac rhythm abnormalities related to electrocution injuries are usually observed at the time of the incident. If the patient's overall clinical condition is good and they have a normal ECG at the time of admission to the ED, the probability of observing any delayed serious dysrhythmia is unlikely.

Key Words: Electrical injury; cardiac monitoring.

AMAÇ
Elektrik çarpması kazasıyla yaralanan hastaların, monitörizasyon ve izlem için acil servise kabulü tartışmalıdır.

GEREÇ VE YÖNTEM
Son 20 yıl içinde, elektrik kazası nedeni ile erişkin acil servise başvuran 102 hastanın (86 erkek, 16 kadın; ort. yaş 29.5; dağılım 18-68 yaş) kayıtları değerlendirildi.

BULGULAR
Üçü düşük, altısı yüksek voltaj teması nedeniyle toplam dokuz olguda ölüm görüldü. Bir sepsis olgusu dışında, diğer olguların hepsinde ölüm, olayın hemen sonrasında gelişen erken ritim bozukluklarına bağlı idi. Yaşayan hastalarda izlenen EKG bulguları; 70'inde normal, 8'inde sinüs taşikardisi, üçünde sinüs bradikardisi, dördünde ST-T dalga değişiklikleri, birinde ventriküler ekstrasistol olup, yedi olguda EKG kayıtlarına ulaşılamadı. Olguların 72'si tekrarlayan EKG çekimleri ile izlendi. Yaşayan hastaların hiçbirinde medikal ya da elektriksel tedavi gerektirecek herhangi bir EKG değişikliği izlenmedi.

SONUÇ
Elektrik yaralanmalarına bağlı kardiyak ritim anomalileri genellikle olay anında görülür. Eğer hasta klinik olarak iyi, acil servise kabulünde normal EKG'ye sahip ise, gecikmiş ciddi bir ritim bozukluğu görülme olasılığı pek mümkün değildir.

Anahtar Sözcükler: Elektrik yaralanması; kardiyak monitörizasyon.

Almost all electrical injuries are admitted to the emergency department (ED). Although they are not seen commonly, these incidents are associated with a high degree of morbidity and mortality since the injury can affect various systems of the body.[1] The magnitude of voltage to which the victim has been exposed, the resistance of the body, exposure to either direct or alternating current, the duration of exposure, and the pathway of the current inside the body all affect the potential mortality and morbidity.

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High-voltage injuries occur at 1,000 volts or greater. These are most commonly work- related injuries and typically observed in males. Low-voltage injuries (<1000 volts) are usually observed in females and children as domestic injuries. Though high-voltage electrical injuries are more dangerous, low-voltage electrical injuries are observed more frequently.[2]

Electrocution accidents can lead to injuries in 3-54% of exposed patients, and the severity can range from minimal to life-threatening injuries.[2-7] The cardiovascular, musculoskeletal and nervous systems, kidneys, and skin are most affected, with the primary cause of death being cardiac arrest. It is also known that the serious cardiac effects usually occur just after the injury. Beyond this period, the ideal length of time for observation and monitoring has been a source of controversy among clinicians.

The present study evaluates the cardiac problems in electrically injured patients via a review of the records of clinical findings, ECG findings, cardiac enzyme levels, and monitoring. In addition to the identified cardiac problems and injuries, we aimed to determine the necessary duration of observation.

MATERIALS AND METHODS

We evaluated the records of patients with electrical injury admitted to the adult ED of Hacettepe University Medical Center over the past 20 years after obtaining the approval of the ethical committee. A total of 215 patients were found, with 113 patients excluded due to insufficient hospital records. One hundred and two patients were included in the study. Data regarding age, sex, cause of electrical injury, type of current, incident time, hospital admission time, symptoms during admission, hospital stay, cause of death, rate of ED discharge and admittance to wards, duration of observation for cardiac complications, ECG changes during the observation period, and cardiac enzyme levels were collected. Data recorded for the purpose of this study are presented as frequencies and percentages. All data were evaluated retrospectively using the Statistical Package for the Social Sciences (SPSS) 17.00 (Chicago, IL, USA).

RESULTS

There were 102 patients aged between 18 and 68 years, with a median age of 29.45±11.7 years. Eighty-four percent (n=86) of the patients exposed to electricity were male and 16% (n=16) were female. The mean age of males was 29±11 years and of women 32±12 years.

Fifty percent (n=51) of the patients were admitted to the ED within the first 30 minutes (min) after the incident, 25% (n=26) between 30-60 min, 11% (n=11) between 1-2 hours (h), 11% (n=11) between 2-4 h, and the remaining 3% (n=3) were admitted after 5 h. The time periods of admissions were as follows: 58% (n=59) between 08:00-17:00, 36% (n=37) between 17:00-24:00, and 6% (n=6) between 24:00-08:00. Approximately 33% of all admissions (n=34) were between 13:00-15:00.

Thirty-nine percent (n=40) of injuries occurred at work, 37% (n=38) at home, and 24% (n=24) on the street outside home or work.

Sixty-seven percent (n=68) of the injuries resulted from a low-voltage current, while 33% (n=34) resulted from a high-voltage current. Thirty-seven percent of the low-voltage injuries (n=25) were from an electric cable, 21% (n=14) from a power outlet, 22% (n=15) during the repair of an electric-powered household gadget, 10% (n=7) from an electric heater, 3% (n=2) from a light bulb, and 7% (n=5) due to other reasons.

Sixty-eight percent (n=23) of high-voltage injuries resulted from contact with a high-voltage line and the remaining 32% (n=11) from contact with an electrical transformer. The presenting symptoms were as follows: 55% (n=56) burns alone, 16% (n=16) trauma with loss of consciousness, 8% (n=8) cardiac arrest (accompanied by trauma in 5 patients), 6% (n=6) burns and trauma, 5% (n=5) burns and loss of consciousness, and 5% (n=5) pain and numbness at the area of contact; the remaining 5% (n=6) were asymptomatic (Table 1).

Of 21 patients with loss of consciousness, two-thirds were exposed to low-voltage electrical current and one-third to high-voltage electrical current. Forty-five low-voltage and 22 high-voltage burns were observed. Eighteen major and 49 minor burns were observed.

The 15 low and 12 high-voltage electrical injuries were accompanied by trauma in a total of 27 cases, of which 19 were minor and 8 were major traumas.

The electrical axis was parallel to the body axis in 28% (n=29), vertical to the body axis in 26% (n=27), and unknown in 45% (n=46) of the patients. The electrical axis was inclusive of vital organs in 36% (n=37) patients and non-inclusive in 19% (n=19). Inclusion was not evident in 45% (n=46).

The survival rate was 91% (n=93). Sixty percent (n=64) were discharged from the ED. The observation times of the discharged patients in the ED were as follows: 3% (n=2) in 0-1 h, 9% (n=6) in 1-2 h, 27% (n=17) in 2-4 h, 55% (n=35) in 4-24 h, and 6% (n=4) in more than 24 h.

Hospitalization rates were as follows: 20% (n=19) to the burns unit, 4% (n=4) to intensive care, 3% (n=3) to the orthopedics and trauma unit, and 3% (n=3) to other units.

Table 1. The distribution of the victims according to symptoms and type of electrical current

Presenting symptom	Low-voltage (n)	High-voltage (n)	Total (n)
Burn	38	18	56
Loss of consciousness & trauma	10	6	16
Asymptomatic	5	1	6
Burn & trauma	3	3	6
Pain & numbness	5	0	5
Loss of consciousness & burn	4	1	5
Cardiac arrest & trauma	2	3	5
Cardiac arrest	1	2	3

The initial ECG findings in surviving patients were as follows: 76% (n=70) normal, 9% (n=8) sinus tachycardia, 3% (n=3) sinus bradycardia, 4% (n=4) ST-T wave changes, and 1% (n=1) premature ventricular contractions. ECG records could not be found for 7% (n=7) of the surviving patients.

ECG monitoring was performed in 71% (n=72) of the cases. Patients with sinus tachycardia initially returned to normal sinus rhythm. Excluding the 8 cases of cardiac arrest that developed at the time of the event and one case of sepsis, no ECG changes requiring medical or electrical therapy were observed.

The cardiac enzymes of these patients were tested. They were high in 4% (n=4); however, these patients were not diagnosed as having acute coronary syndromes (Table 2).

A total of 2 females and 7 males died. The mean age of mortality was 23, and all were occupational accidents; 3 had been exposed to low-voltage electricity and 6 to high-voltage electricity. Five patients also had serious trauma. One died because of delayed sepsis; 7 had asystole and 1 had ventricular fibrillation (VF) at the time of admission to the ED.

DISCUSSION

More than 80% of patients injured as a result of electrocution at the workplace are male, as presented in many studies.[8,9] The findings of the present study are consistent with the literature, which suggests a large proportion of occupational electrical injuries are seen in young men. This is probably due to the fact that the vast majority of workers in the electrical industry are men.

Although the majority of the injuries in this study occurred as a result of contact with a low-voltage source, most of the deaths occurred as a result of high-voltage injuries. In addition to the voltage of the current, the path of the current through the body, the resistance of the tissue and exposure to either alternative or direct current are important factors affecting morbidity and mortality. Although the records under review revealed that three of the deaths were caused by low-voltage electricity, all these patients' vital organs had been affected by the electrical current and two cases also had severe trauma.

Both low- and high-voltage injuries can cause trauma. However, high-voltage current causes large single muscle contractions. Since the victim is thrown by these contractions, secondary traumas are more common in high-voltage current injuries. Therefore, patients subjected to electrical injury should be evaluated carefully and the possibility of multiple trauma should be considered.[10]

In the present study, the mortality rate was 9%, which is similar to previous reports.[11] Aside from one case of sepsis, the other eight deaths occurred due to

Table 2. Cardiac monitoring results in the surviving patients

ECG finding	Initial ECG (n)	Low voltage (n)	High voltage (n)	ECG monitoring (n)	Elevated cardiac enzymes (n)	Treatment (n)
Normal	70	54	16	16	2	–
Abnormal	16	6	10	10	2	–
Sinus tachycardia	8	3	5	5		–
Sinus bradycardia	3	1	2	2	2	–
ST-T changes	4	2	2	2		–
Premature ventricular contraction	1	–	1	1		–
No record	7	5	2	2	–	–
Total	93	65	28	28	4	–

cardiac problems that started at the time of electrical injury.

High-voltage injuries generally cause asystole; however, low-voltage injuries more commonly cause VF. Seven asystole cases were observed at the time of admission to the ED. The initial cardiac rhythm may have been different immediately following the accident, and it is possible that the patient may have developed asystole during transportation to the ED. Only one victim who had been injured by low-voltage electricity had VF rhythm on arrival to the ED.

More than half of the patients had been kept in the observation unit for 4-24 hours in the Medical Center. The necessity of observation and ideal monitoring period for patients who have suffered electrocution is under debate. Inclusion criteria as well as the monitoring periods were different in the published studies. The monitoring periods in the studies are usually 6 h,[12] 6-8 h[9] and 24 h.[2,4,13] Some of the studies evaluated patients exposed to high-voltage[4,7,14] or low-voltage [9,12] electricity, while others focused on both low and high voltage.[2]

Electrical current disrupts the normal electrophysiological system by causing thermal and ischemic myocardial injury. Often, sinus tachycardia and premature ventricular contractions are observed, but serious rhythm disturbances such as asystole and VF may also occur. Some authors propose cardiac monitoring [15-17] after each shock, while other authors comment that it is unnecessary.[4,9,13,18] Cunningham[19] did not detect any delayed dysrhythmias in the survey sent to 56 ED directors (with 32 respondents). Purdue and Hunt[4] evaluated 48 high-voltage-related electrical accidents with normal initial ECG, and they reported that 48-h monitoring was unnecessary. Cardiac monitoring is recommended in cases where there is loss of consciousness or documented rhythm disorder at the incident site, and in cases with abnormalities occurring in the 12-lead ECG at the time of admission. Some authors propose monitoring, claiming that myocardial injury can occur if the electrical current passed the body through the vertical axis and caused excessive cutaneous burns.[2-7] On the other hand, other authors think that if the initial 12-lead ECG is normal and there has been no loss of consciousness, it is unlikely that delayed cardiac rhythm disturbances will be seen; thus, it is not necessary to monitor the victim for 24 h.[2-13]

It has been shown in a few studies that dysrhythmias could develop hours or days after the accident. [3,4] Jensen[15] identified delayed arrhythmias 8-12 h after the accident in three cases, of which two were domestic injuries. In all these cases, the electrical current passed through the thorax. One had recurrent VF, one had ventricular tachycardia (VT), and one had ventricular parasystoles. Endometrial biopsies of two patients showed patchy myocardial fibrosis and increased numbers of Na^+ and K^+ pumps, suggesting arrhythmogenic focus. However, researchers were not able to observe any elevation of cardiac enzymes. Due to the occurrence of these delayed arrhythmias, Jensen[15] proposed the necessity for 24-h monitoring of patients injured by electricity; however, the patients reported by Jensen had been admitted late to the ED and there had been no ECG taken immediately after the accident. Thus, it is difficult to determine whether their cardiac rhythm was normal after the incident. It is more likely that their initial ECGs also revealed dysrhythmias. In the present study, no delayed dysrhythmias were observed regardless of the strength, duration or pathway of the current through the body. Moreover, 36% of cases had injuries including vital organs, 33% occurred by high-voltage, 27% occurred together with trauma, 21% resulted in loss of consciousness, and 17% were accompanied by important findings such as major burns. On the basis of the results, we agree with authors that if the initial ECG of an electrically injured victim is normal and the victim is not seriously injured, delayed important dysrhythmias are unlikely to develop. Therefore, it is not necessary to inconvenience the patient, overcrowd the ED and increase the cost of care[2] by admitting this type of patient for 24-h cardiac monitoring. However, the approach to patients having existing cardiac disease is unclear. Creatine kinase (CK) and isoenzymes specific to the myocardium are not specific in determining cardiac ischemia in electrically injured patients.[5,7,20]

The diagnosis of myocardial necrosis has been defined as CK elevation greater than twice the normal with a positive CK-MB fraction of >3%.[7] Depending on the skeletal muscle damage in electrical injury, CK-MB can also increase.[14,21] According to some authors, the role of CK-MB in the diagnosis of myocardial injury is controversial if there is no pathognomonic ECG evidence of myocardial infarction.[5,13,21] Some authors emphasize the importance of the duration of the elevation of CK-MB levels. As the CK-MB elevations due to skeletal muscle injury will take about 12-24 h, they argue that early elevations in CK-MB levels are related to the myocardial ischemia.[7]

In the present study, cardiac enzyme elevations were only found in four surviving patients. However, because of the late rise in the cardiac enzymes and the lack of clinical findings compatible with ischemia, none of the cases was considered as having acute coronary syndrome.

In conclusion, cardiac rhythm problems due to electrical injuries are observed during or immediately after the event. The risk of development of a serious

delayed dysrhythmia is very low if the patient's general condition is good and there is no loss of conscious, major trauma, cardiac disease, or ECG abnormalities at the time of ED admission. Therefore, it is not necessary to observe this cohort of patients for rhythm problems.

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