Case Report

SAGE Open Medical Case Reports

SAGE Open Medical Case Reports
Volume 8: 1–4

DOI: 10.1177/2050313X20920421
journals.sagepub.com/home/sco
SAGE

Evaluating the risks of arrhythmia following electrical injury: Two cases of electrical injuries in the upper limbs

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Abstract

Electrical injuries induce ventricular arrhythmias, which are lethal. Therefore, it is important to evaluate the risk of arrhythmias at initial presentation to the emergency department in cases of electrical injuries. Here, we report two cases with electrical injuries, where current flowed between the upper limbs, requiring 24-h hospitalization for arrhythmia monitoring. The patients were 57- and 30-year-old men, who sustained separate electrical injuries (6600 V, line voltage), with current flow from one hand to the other. They did not develop any ventricular arrhythmias during hospitalization and were discharged. The risk for ventricular arrhythmias is lower for electrical injuries occurring between the upper limbs than for those occurring between the upper and lower limbs. We conclude that 24-h hospitalization for monitoring of patients with electrical injuries of the upper limbs may be sufficient.

Keywords

Electrical injury, ventricular arrhythmias, emergency

Date received: 2 September 2019; accepted: 26 March 2020

Background

Electrical injuries can result in potentially fatal cardiac arrhythmias.[1] Therefore, it is essential to predict the occurrence of arrhythmias at the time of presentation to the emergency department for electrical injuries. The characteristics of the injury, such as the path of the current flow and electric resistance of the contact area, may be indicative in the prediction of arrhythmias. Transthoracic current, including that passing between the upper extremities, may be considered as one of the possible risk factors for arrhythmias.[2–4] Here, we report two cases with electrical injuries from high-voltage current of a 6600 V line passing between the upper limbs, who were hospitalized for 24 h for arrhythmia monitoring.

Case 1

A 57-year-old man touched a high-voltage transformer from the rooftop of an apartment building and sustained an electrical injury due to current (6600 V, line voltage) passing from one hand to the other. He fainted, and his face was injured as a result of the fall. He was transferred to our hospital following an emergency medical service request placed by witnesses. The vital signs of the patient at the time of admission were as follows: blood pressure, 139/84 mmHg; heart rate, 77 beats/min; respiratory rate, 14 breaths/min; body temperature, 35.8°C; blood oxygen saturation (SpO_2), 94% (room air); and Glasgow Coma Scale (GCS), 14 (E4V4M6). Physical examination revealed that the entrance and the exit points of the current were his hands, as indicated by the presence of second-degree burns (Figure 1). Laboratory tests revealed an elevation in the levels of creatine kinase (522 IU/L), glucose (178 mg/dL), fibrinogen degradation product (17.3 μg/mL), and D-dimer (9.03 μg/dL). Regular sinus rhythm with no arrhythmias was observed on the 12-lead electrocardiogram (ECG) on admission. Since he fainted owing to the electric shock, computed tomography of the

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facial bones was performed, and the results showed a fracture of the orbital floor and the medial wall of the maxillary sinus. He was admitted for 24-h observation to assess the risk of ventricular fibrillation. No signs of arrhythmia were observed during his hospital stay, and he was therefore discharged.

Case 2

A 30-year-old man was inspecting electrical equipment wearing rubber gloves; he sustained an electrical injury due to current (6600 V, line voltage) passing from his right to left hands upon touching an iron bar (Figure 2). Following the accident, he was alert; however, his rubber gloves were torn. When he was transferred to our hospital, his vital signs were as follows: blood pressure, 141/88 mmHg; heart rate, 80 beats/min; respiratory rate, 16 breaths/min; body temperature, 36.5°C; SpO_2, 98% (room air); and GCS, 15 (E4V5M6). Physical examination revealed injuries in his left thumb and hands. The torn rubber gloves showed that the path of the current was through his upper limbs. The results of laboratory examination, chest radiography, electrocardiography, and ultrasonic inspection were normal. Regular sinus rhythm with no arrhythmias was observed on the 12-lead ECG on admission. He was hospitalized for 24-h observation and was discharged when no signs of arrhythmia were observed during his stay. Flap formation and skin grafting surgery was conducted on the 10th day after his discharge.

Figure 1. Electrical injuries on both palms of the patient in case 1.

Discussion

We report the cases of two individuals who sustained electric injuries and successfully recovered without developing arrhythmias. Electrical injury can be fatal owing to complications such as ventricular fibrillation or coronary artery thrombosis and dissection.[5] Guidelines recommend 12-lead electrocardiography and 24-h monitoring after an electrical injury if the patient has any risk factors for arrhythmias.[6] Their necessity and the duration of cardiac monitoring are topics of debate.[1,7,8] According to a previous report, high-voltage (500 V or more) electric shock should be evaluated carefully in the emergency department, using echocardiography and cardiac catheterization.[9] Another report suggested that electric injury cases involving high voltages (>1000 V) or contact with water should be classified as severe cases[10] and states that in such cases, specialized treatment focusing on trauma and burns should be administered at the hospital after a secondary survey and evaluation of circulatory and musculoskeletal systems. The two cases reported here had high-voltage transthoracic electrical current exposure; an

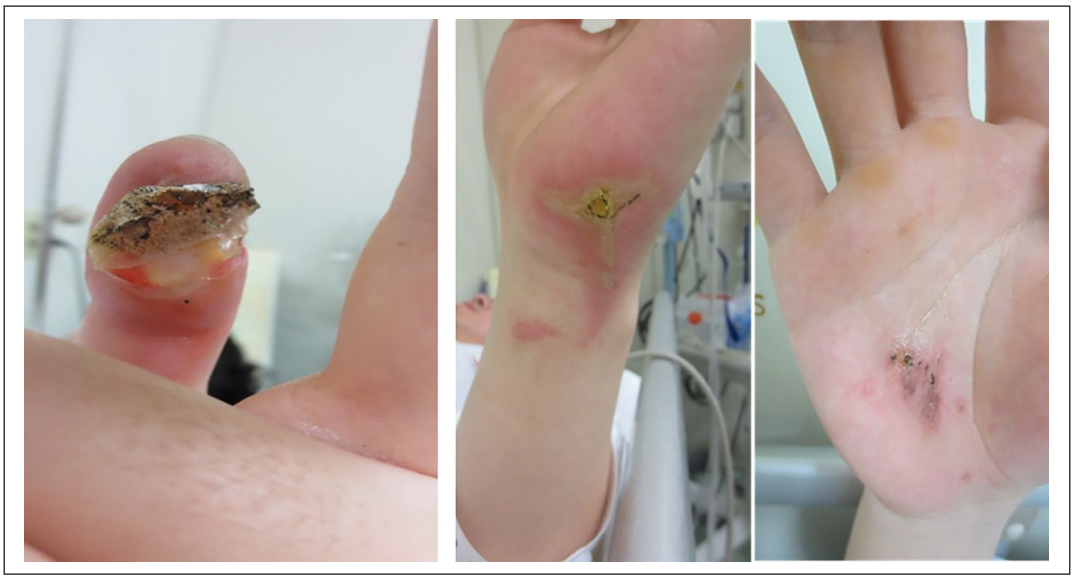

Figure 2. Electrical injuries of the patient in case 2.

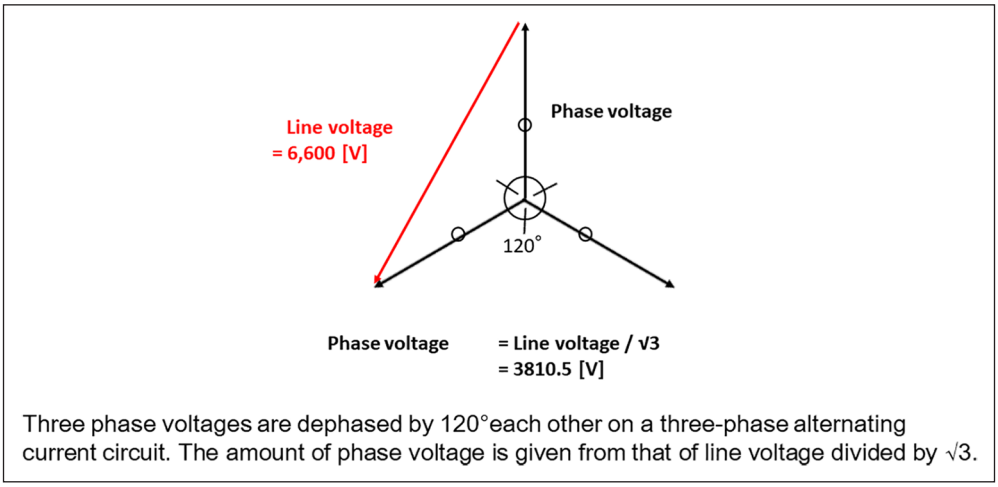

Figure 3. Vector waves of phase and line voltages.

evaluation of the circulatory system was therefore recommended.[10] Cases such as case 1 in this report, where the patient lost consciousness, warrant particular attention.[1,8]

Arrhythmias may occur when the voltage is high, although many factors influence this. We calculated the V_h (threshold voltage for ventricular fibrillation between upper limbs) using the V_{ref} (threshold voltage for ventricular fibrillation between an upper and lower limb), R (body impedance), and F (the heart-current factor). The mean value of R for the path between the upper limbs is 11,300 Ω under dry conditions and that for F is 0.4.[10–12] As the mean value of R between upper and lower limbs is 4800 Ω under dry conditions, in cases where the V_{ref} is 1000 V, the V_h was calculated as follows

$$V_h = (11{,}300/4800)\times(1000/0.4) = 5885\ \text{V}$$

This indicates that arrhythmias may be induced when the voltage exceeds 5885 V in cases where the current path is between the upper limbs. The two cases in our report sustained electrical injuries in their upper limbs with a 6600 V line voltage (three-phase alternating current). The voltage between two of three cables is termed line voltage; therefore, the voltage (phase voltage) affecting these two patients was $6600/\sqrt{3} = 3810.5$ V (Figure 3). As per our calculation, the risk of arrhythmia was considered to be lower when the current path was between both upper limbs than when it was from the hands to feet.

Patients with electrical injuries where the current passes through the hand-to-hand route may only require a short electrocardiographic monitoring period. Therefore, with regard to electrical injuries between both upper limbs, 24-h hospitalization for ECG monitoring may be sufficient; however, only two patients are being reported here, and further study is needed. Furthermore, there is limited evidence from clinical studies to suggest that the current path from the hand to feet or between the upper limbs may influence the risk of arrhythmias.

Regarding cardiac complications in patients after an electrical injury between upper limbs, it would be a suitable option to prolong hospitalization in some situations, such as for a voltage higher than 5885 V, a longer duration of current flow, or in the case of abnormal skin conditions, such as ruptured or wet skin. Other injuries also may require prolonged hospitalization.

Conclusion

We encountered two patients with electrical injuries who underwent 24-h cardiac monitoring for the observation of arrhythmias. A 24-h period of cardiac monitoring appears to be sufficient in such cases, and extended monitoring may be recommended when the voltage exceeds 5885 V, there is a longer duration of current flow, or if the skin condition is abnormal, as in the case of ruptured or wet skin.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics approval

Our institution does not require ethical approval for reporting individual cases or case series.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Informed consent

Written informed consent was obtained from the patient(s) for their anonymized information to be published in this article.

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