Dual tachycardia induced by electrocution terminated by an implantable cardioverter-defibrillator

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Introduction

The various effects of electrical injury include skin burns, internal organ damage, direct myocardial damage, and cardiac arrhythmias.[1,2] High-voltage shocks, defined as shocks from sources >1000 volts (V), may result in myocardial necrosis, cardiac standstill, and sudden cardiac death. On the other hand, low-voltage shocks, those with <1000 V, particularly with alternating current seen in household electrical systems, may result in cardiac stimulation resulting in atrial fibrillation (AF) or ventricular fibrillation (VF). Appropriate detection and termination of VF resulting from alternating current shock by a single-chamber implantable cardioverter-defibrillator (ICD) has previously been reported.[3,4] We report a case of dual tachycardia, both AF and VF, induced by an electrical shock that was appropriately detected and terminated by dual-chamber ICD.

KEY TEACHING POINTS

- Electrical injury and electrocution are relatively common in the United States. The various effects of electrical injury include skin burns, internal organ damage, direct myocardial damage, and cardiac arrhythmias.
- High-voltage shocks, defined as shocks from sources >1000 V, may result in myocardial necrosis, cardiac standstill, and sudden cardiac death. Low-voltage shocks, defined as shocks from sources <1000 V, particularly with alternating current seen in household electrical systems, may result in cardiac stimulation resulting in atrial fibrillation or ventricular fibrillation.
- The presence of a dual-chamber implantable cardioverter-defibrillator offers unique insights into the initiation of cardiac arrhythmias by electrical injury and electrocution.

Case report

A 46-year-old man with a nonischemic cardiomyopathy and a primary prevention dual-chamber ICD was working at an outdoor construction site when he was observed to come in contact with a live 277/408 V wire. A co-worker witnessed the event and reported that the patient suddenly lost consciousness and fell to the ground from a 6-foot ladder after inadvertently grabbing ahold of the wire with both hands. The patient quickly regained consciousness after hitting the ground. Emergency responders arrived at the scene to evaluate the patient, who was, at that point, completely conscious.

Physical examination in the emergency room revealed full-thickness electrical burns of both hands. His heart rate was normal with a regular rhythm. Other vital signs were within normal limits. Lab work was unremarkable, including a high-sensitivity troponin level of 7. Electrocardiogram revealed normal sinus rhythm (NSR) with left ventricular hypertrophy. Telemetry monitoring disclosed NSR.

Interrogation of his Boston Scientific Dynagen dual-chamber ICD documented the event (Figure 1). NSR was noted prior to the onset of electromagnetic interference (EMI) caused by alternating current electrical shock, which was detected on atrial, ventricular, and shock electrograms (EGMs). EMI, in total, lasted for approximately 10 seconds. Following termination of EMI, both AF and VF were noted on intracardiac EGMs, resulting in detection of VF (Figure 1). The device delivered an appropriate 41 joule (J) shock, which restored NSR at a rate of 75 beats per minute with intermittent atrial and ventricular complexes (Figure 2).

Discussion

Electrical injury and electrocution are relatively common in the United States, with approximately 4400 patients annually suffering injuries secondary to electrical hazards.[1] Arrhythmia is a frequent cardiac manifestation of electrical injury,[1] while conduction system disturbance and myocardial

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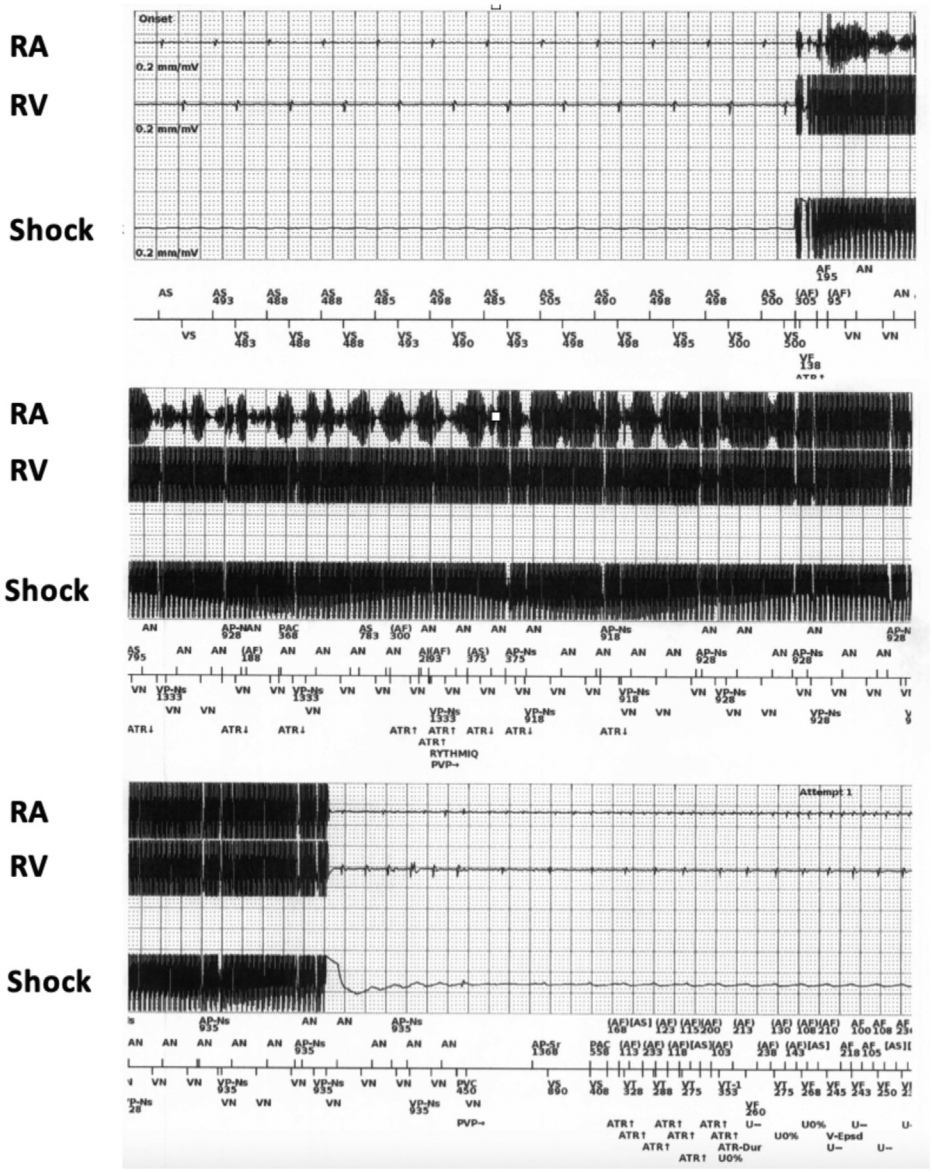

Figure 1 Induction of dual tachycardia by electrical shock. Telemetry from the implantable cardioverter-defibrillator shows noise on both atrial and ventricular channels resulting from a 60 Hz electrical shock. The duration of the electrical shock is in excess of 10 seconds, which results in the induction of both atrial fibrillation and ventricular fibrillation. AN = atrial rate noise; AP = atrial pace; AP-Ns = atrial pace noise; AS = atrial sense; ATR = atrial tachycardia sense; VN = ventricular rate noise; VP = ventricular pace; VP-Ns = ventricular pace noise; VS = ventricular sense.

damage may also occur.[2] The extent of injury depends on current flow, tissue resistance, and duration of the shock.[1] Electrical shocks of more than 1000 V are considered high-voltage shocks. Certain high-voltage lines can carry upwards of 400,000 V, while lightning strikes can produce more than 10 million V.[5] Household current of 100/220 V travels in a cyclical fashion at 60 cycles per second (60 Hertz) and is considered low voltage. Systems of 277/408 V, such as the one contacted by our patient, are frequently used in industrial construction and are also considered low voltage. Low-voltage electrical shock is potentially life threatening given that the threshold for inducing VF may be as low as 50–100 milliamps and the average resistance of the human body is 500 ohms.[1] In addition, the frequency of 60 Hertz used in typical household current increases the likelihood that the heart may be exposed to current during its vulnerable period, inducing arrhythmia such as AF or VF.[6,7] Low-voltage alternating current is more likely to induce cardiac arrest via VF, as opposed to direct current and high-voltage alternating current sources, which are more likely to induce cardiac standstill.[1,8] Furthermore, alternating current can be used for induction of VF during ICD defibrillation testing.[9]

In our patient, the presence of dual-chamber ICD offered unique insights into the initiation of cardiac arrhythmias by electrical shock. Intracardiac EGMs revealed that alternating current produced EMI on the telemetry recordings, documenting the duration of exposure to the alternating current (approximately 10 seconds) that induced AF and VF.

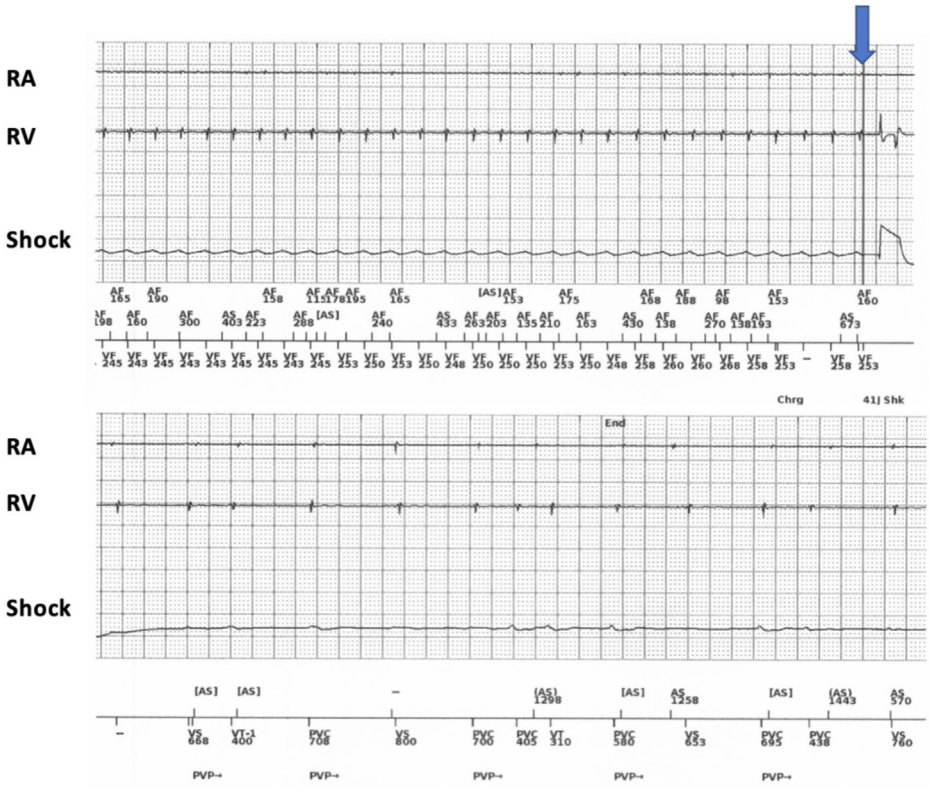

Figure 2 Termination of both atrial fibrillation (AF) and ventricular fibrillation (VF) by 41 joule shock. Telemetry demonstrates appropriate detection of ventricular fibrillation with resultant delivery of 41 joule shock (*arrow*), which terminates both arrhythmias. AS = atrial sense; PVC = premature ventricular complex VS = ventricular sense; VT = ventricular tachycardia.

Following the induction of arrhythmia, the device appropriately detected VF and terminated the dual tachycardia. While damage to the ICD system is unlikely as a result of electrical shock, postevent interrogation allows for documentation of both the event and subsequent integrity of the system.

Conclusion

This case highlights that arrhythmias may be induced with exposure to low-voltage alternating current, provided there is enough current flow delivered for sufficient duration.

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