Case Reports

Inappropriate Implantable Cardioverter-Defibrillator Shocks

Attributed to Alternating-Current Leak in a Swimming Pool

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Implantable cardioverter-defibrillators (ICDs) are the standard of care for preventing sudden cardiac death in patients who are predisposed to malignant ventricular arrhythmias. Causes of inappropriate ICD shock include equipment malfunction, improper arrhythmia evaluation, misinterpretation of myopotentials, and electromagnetic interference. As the number of implanted ICDs has increased, other contributors to inappropriate therapy have become known, such as minimal electrical current leaks that mimic ventricular fibrillation. We present the case of a 63-year-old man with a biventricular ICD who received 2 inappropriate shocks, probably attributable to alternating-current leaks in a swimming pool. In addition, we discuss ICD sensitivity and offer recommendations to avoid similar occurrences. ***(Tex Heart Inst J 2014;41(1):61-3)***

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Implantable cardioverter-defibrillators (ICDs) provide primary and secondary prevention of sudden cardiac death in patients who are predisposed to malignant ventricular arrhythmias.[1-3] Despite the clinical efficacy and improved technical specifications of newer ICDs, inappropriate shocks can still affect patients who have implanted devices. We review the case of a patient whose inappropriate ICD shocks were most likely caused by the leakage of small amounts of alternating current in a swimming pool.

Case Report

A 63-year-old man with a history of atrial fibrillation, coronary artery disease, myocardial infarction, multivessel coronary artery bypass grafting, and ischemic cardiomyopathy presented at our electrophysiology clinic for device interrogation. Two months earlier, the patient's previous permanent pacemaker had been upgraded to a biventricular ICD: a Protecta™ XT model D314TRG CRT-D (Medtronic, Inc.; Minneapolis, Minn) with battery voltage of 3.1645 V. The atrial lead was a 52-cm FINELINE® II EZ STEROX model 4470 (Boston Scientific Corporation; Natick, Mass), implanted in 2008; the right ventricular lead was a 65-cm 6947 Sprint Quattro® (Medtronic), implanted in 2008; and the left ventricular lead was a QuickFlex™ µ LV, model 1258T (St. Jude Medical, Inc.; St. Paul, Minn), implanted in 2011. The patient had experienced 2 distinct device discharges immediately after jumping into a swimming pool while vacationing in St. Lucia approximately 2 weeks before the current presentation. He described no prodromal symptoms, chest pain, palpitations, dizziness, syncope, or aftereffects. A cardiologist in St. Lucia had ruled out ischemia, heart failure, and electrolyte disturbances.

Interrogation of the ICD revealed 2 shocks for electrical activity that the device had interpreted as ventricular fibrillation (Fig. 1). The remainder of the interrogation report revealed normal function, sensing, and evaluation of thresholds by iterative output testing; 3 unrelated episodes of paroxysmal atrial fibrillation had not evoked therapy. The discharges corresponded with the times when the patient was in the swimming pool.

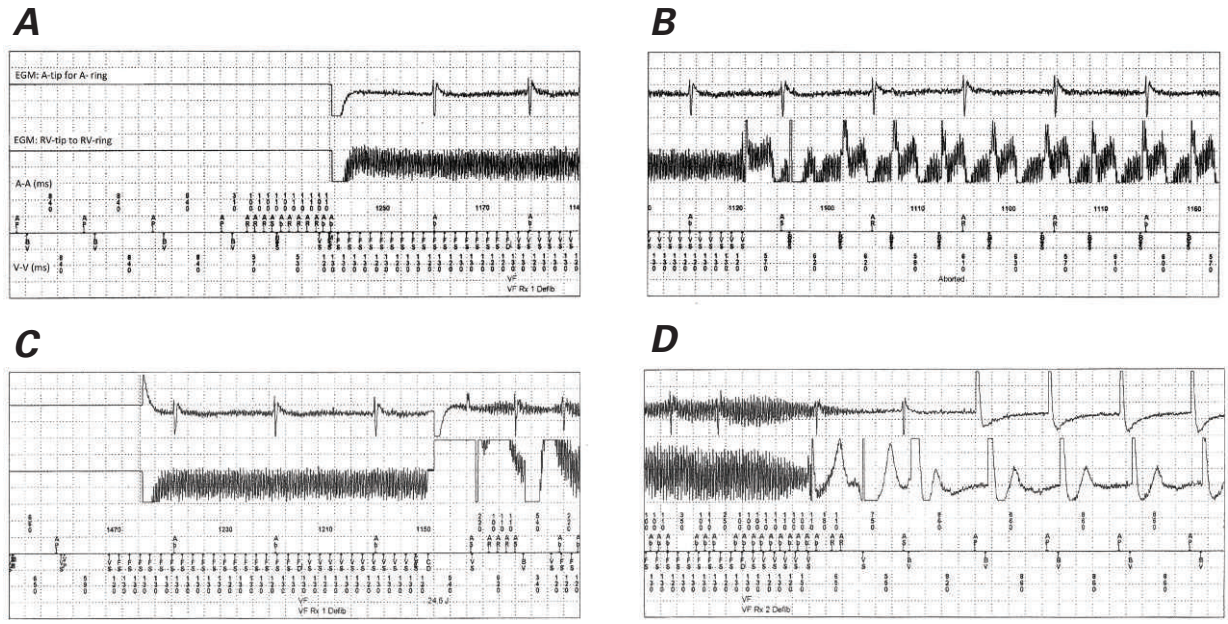

Fig. 1 ***A****) Initial portion of electrogram strip shows substantial noise and electromagnetic interference. The interference corresponds to the time when the patient was in the swimming pool.* ***B****) Continuation of electrogram shows noise, interpreted by the device as an intrinsic ventricular signal.* ***C****) Continuation of electrogram shows electromagnetic interference, interpreted as ventricular fibrillation and evoking 2 shocks.* ***D****) Electrogram shows the termination of electromagnetic interference and resumption of biventricular pacing, most likely corresponding to when the patient was pulled from the swimming pool.*

AP = atrial pacing; AR = atrial refractory; BV = biventricular pacing; CD = charge delivered; CE = charge ended; FS = ventricular fibrillation sensed; VS = ventricular-sensed

Discussion

From 12% to 21% of ICD patients receive at least one inappropriate shock at some point after device implantation. Causes of inappropriate discharge include external noise, atrial dysrhythmias or oversensing, muscle myopotentials, lead-connector or mechanical faults, and electromagnetic interference (EMI).[4] Inappropriate discharge for improperly sensed atrial dysrhythmias remains relatively frequent; however, advanced technological specifications used in the production and programming of newer devices have minimized EMI as a cause of inappropriate discharge.

Inappropriate shocks have been associated with adverse overall outcomes and decreased quality of life. The occurrence of inappropriate therapy has been associated with a doubled overall mortality rate from proarrhythmia, hemodynamic compromise, or the direct mechanical effects of the shocks themselves.[5] It is therefore crucial to anticipate and optimally avoid possible causes of EMI.

Inappropriate therapy attributable to EMI can occur if a mechanically paced patient comes into direct contact with the source emitting the signal, or even if the ICD or PPM is within the source's electromagnetic field.[6] Environmental sources of EMI include digital music players and headphones, screening equipment in airports, refrigerators, TASERs, and even casino slot machines. Effects include improper mode-switching, asynchronous pacing, and inappropriate antitachycardia pacing or shocks.[7] The various types of EMI can be classified in accordance with the frequency of the encountered energy and the electromagnetic field's strength.

Contact with even minimal amounts of electricity can prove hazardous to patients who have a PPM or ICD, especially the latest-generation leads and devices. Homes or recreational facilities might have equipment installed improperly or electrical systems that are not grounded sufficiently to counteract leaking current. Some PPMs and ICDs can detect alternating current as low as 10 μA, depending on their sensitivity settings.[8] It is difficult to detect such minute levels of leaking alternating current with use of commercial testing devices. In specific regard to our patient's case, the testing of electrical current in a swimming pool might not be routine.[6]

Few reported cases of inappropriate device therapy have been attributed to electrical current in water. Lee and colleagues[6] reported the case of a 70-year-old patient with a Medtronic GEM® model 7227 ICD who was shocked 5 times while swimming in a pool. Garg and associates[9] reported the case of a child with left ventricular noncompaction and a Medtronic Micro Jewel™ II 7223Cx who was shocked inappropriately after entering a swimming pool and once again after using a shower powered by an electric generator. Chan and co-authors[10] described 2 cases of inappropriate discharge. The first in-

volved a man with a Medtronic Jewel Plus® Active Can® 7220C who was operating a power drill outdoors in the rain; the other was a man with a Medtronic GEM® II DR model 7271 who touched a washing machine with his wet hand. Of note, all of the abovementioned patients had leads with integrated bipolar sensing. The sensitivity of every ventricular lead was set at 0.3 mV, the lowest possible value. At this setting, newer devices can detect even minimal levels of electrical activity.

Bipolar sensing can minimize the effects of EMI. In a true bipolar lead, the defibrillation coil and the ring electrode are separate and have independent conductors. However, in an integrated bipolar lead, the defibrillation coil also serves as the ring electrode, which results in a larger sensing vector (distance from the defibrillation coil to the can). The farther apart the 2 points are from which a device is programmed to collect information, the more susceptible the patient is to EMI.[11] Integrated bipolar sensing technology can filter far-field signal potentials and focus on local myocardial potentials; however, the gathered information differs because of the altered field of view.[12] Despite the differences between integrated and true bipolar sensing, both methods appear to be clinically effective. Currently, most devices are equipped with integrated sensing, as was our patient's ICD.[13]

Although increased ICD sensitivity can protect patients who are predisposed to malignant ventricular dysrhythmias, it comes at the price of potentially oversensing environmental stimuli. Electricity is delivered by means of alternating current, usually at a frequency of 50 to 60 Hz. In our patient, the alternating current was misinterpreted as ventricular fibrillation at an average cycle length of approximately 130 ms. The use of true bipolar sensing can minimize much detection of EMI, but at the cost of a narrower detection vector. Also potentially helpful is the use of an auto-adjusting algorithm, as well as auto-gain.[12] Further discoveries in this area might minimize day-to-day activity restrictions in patients with implanted devices.

Despite all the improvements in device performance, lead technology, and programming that were not foreseeable even 10 years ago, inappropriate discharge remains a challenge that can lead to morbidity and death. We think that more research and development should focus on updating devices so that they filter common EMI sources and still detect myocardial signals associated with dysrhythmias. Meanwhile, clinicians should advise patients to avoid potential hazards, including swimming pools that might contain leaking alternating current. In addition, pool manufacturers should be advised of this risk to ICD and PPM patients and be urged to minimize electrical leaks.

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