Swimming pool saline chlorination units and implantable cardiac devices: A source for potentially fatal electromagnetic interference

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Introduction

Electromagnetic interference (EMI) resulting in inappropriate implantable cardioverter-defibrillator (ICD) shocks or pacemaker inhibition is particularly dangerous while swimming.[1] Although incidents of EMI from alternating current (AC) electrical faults in pools have been described in the literature, they have been sporadic.[2–5] In this series, we describe a new source of EMI within saline chlorination/electrolytic pool cleaning systems. Most large pool sanitation systems have adopted this technology, whereby electrical current is directly passed through the pool water containing sodium chloride to generate chloride ions.[6] This intentionally passes current through the swimming pool water and poses a more direct and universal threat to those with implantable cardiac devices.

KEY TEACHING POINTS

- Saline chlorination systems use the principles of electrolysis to generate chlorine from sodium chloride present in pool water. This is a potential source of electrical current in pools and can cause electromagnetic interference (EMI) in implantable devices.
- EMI from standard alternating current electrical sources has a characteristic sinewave appearance due to aliasing and usually is apparent in all leads.
- The amount of leakage current can vary widely with these systems and is not standardized.

Case report

Case 1

A 40-year-old woman received a dual-chamber pacemaker (St. Jude Medical 2210 Accent DR RF, Sylmar, CA) with epicardial leads (RA/RV leads Medtronic 4965, Minneapolis, MN) for heart block after a tricuspid valve replacement for Ebstein's anomaly. Episodes of significant atrial and ventricular noise were apparent when the patient was in her brother's swimming pool. The noise corresponded with her time swimming and the pool used a saline chlorination system (Figure 1A).

Case 2

A 41-year-old woman with history of *l*-transposition of the great vessels was pacemaker dependent with a biventricular defibrillator (Medtronic DTBA1D1 Viva XT; LV Medtronic 4968 CapSure, RV Medtronic 6935 Sprint Quattro Secure S, RA St. Jude Medical 1888TC Tendril ST Optim). Electrograms demonstrated atrial and ventricular noise misinterpreted by the device as ventricular fibrillation, resulting in a single inappropriate shock. The patient was in a saline chlorination pool at the exact time of the episode. Approximately 1 year later, this same patient, while in a different saline chlorination pool, experienced another EMI event at the time of swimming (Figure 1B and C).

KEYWORDS Defibrillator; Electromagnetic interference; Leads; Noise; Pacemaker
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Discussion

Electrolytic cells used to generate chlorine from saline pool water pose a more generalized potential for EMI in patients with implantable cardiac devices. While these cases cannot be proven to be directly related to the saline chlorination units, the mechanistic rationale and the unlikelihood that a single patient had separate EMI events in 2 separate saline pools supports causality. Electrolytic cells utilize direct current, which would not produce classic AC EMI patterns. However, the power supplies for these systems commonly use switch mode power supplies that can generate rectified output at frequencies similar to the AC source. It is likely that susceptibility to the type of EMI described requires a variety of unfavorable conditions to be present, such as the oscillatory outputs from the electrolytic cells used in many manufacturers' systems mentioned above, in addition to unipolar/

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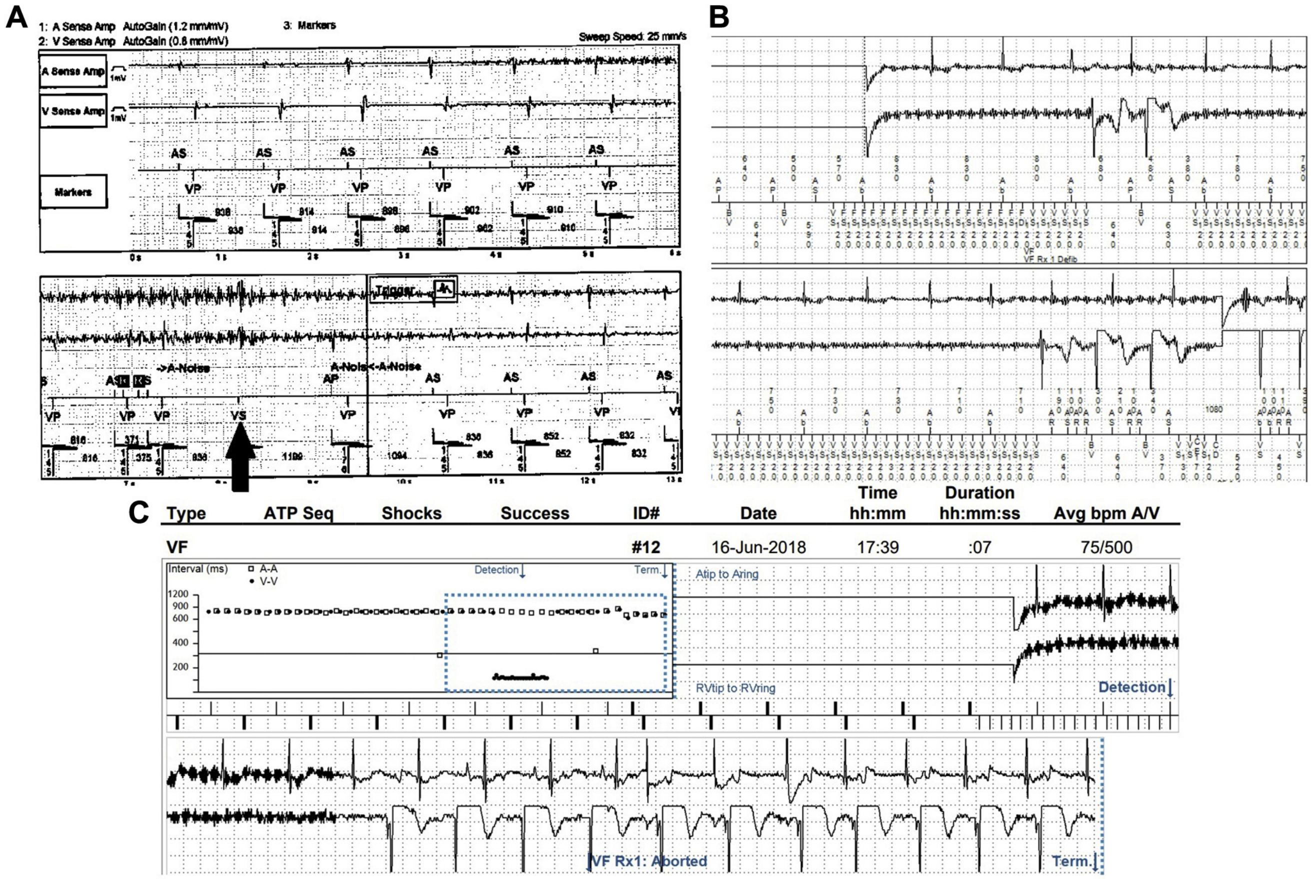

Figure 1 Three electromagnetic interference (EMI) detections while in a saline-chlorinated pool. All noise detections were confirmed to occur during swimming. **A:** A characteristic 60 Hz pattern of EMI resulting in atrial noise detection and transient ventricular pacing inhibition (*arrow*) during swimming in a saline-chlorinated pool. **B:** Noise while in a saline-chlorinated pool resulting in inappropriate implantable cardioverter-defibrillator shock. The EMI is apparent on both the atrial and ventricular sensing channels. **C:** A second event of EMI in a single patient in a different saline-chlorinated pool with aborted therapy.

large-area sensing configurations or insulation breaches. We believe this may represent an important safety counseling aspect in patients with implantable cardiac devices, especially in cases of pacemaker dependence or presence of ICD once the true incidence of this phenomenon is known.

Surprisingly, we could not find rigid standards for the leakage current tolerances allowed for these systems, and "sacrificial anodes" to absorb leakage current are not universal or mandated. In vitro testing of cardiovascular implantable electronic device–lead combinations in conjunction with various saline-chlorination systems are underway. Zinc anodes are commercially available for purchase in these systems to reduce galvanic corrosion of metal fixtures within swimming pools, indicating a meaningful and universal potential for electrical leakage within the pool itself.

Conclusion

We present a mechanistic explanation and a general source of EMI from modern saline chlorination systems commonly used in swimming pools.

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