Troubleshooting the Malfunctioning Implantable Cardiac Defibrillator: A Systematic Approach

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KEYWORDS

• Implantable cardiac defibrillator • Troubleshooting • Management • Oversensing • Lead fracture • Ventricular arrhythmias

KEY POINTS

- Implantable cardiac defibrillators (ICDs) have evolved prominently since their introduction, with broader indications as primary prevention.
- ICDs have become extremely complex and offer many programmable parameters.
- A physician should be thoroughly familiar with the nuances of each model to confirm or dispute the diagnosis made by the ICD as well as reprogram the parameters with a view to adapting them specifically to the characteristics of individual device recipients.
- A systematic stepwise approach (clinical history, physical examination, radiographic techniques, and an analysis of the stored electrograms) is essential for correctly identifying the cause of suspected defibrillator malfunction.

INTRODUCTION

Implantable cardiac defibrillators (ICDs) have evolved prominently since their introduction in clinical practice in 1980. The indications for implant of the original shock boxes were limited to secondary prevention after the survival of at least 2 episodes of sudden cardiac death. The devices delivered only high-energy monophasic shocks between pericardial patches implanted by cardiac surgeons.[1–3] Practice guidelines, based on large international clinical trials, include primary prevention as an indication for implantation of ICD, and the devices are most commonly implanted by cardiologists, using endocardial leads. Antitachycardia pacing (ATP) therapy limits the need to deliver shocks, and the programmable shock polarity and waveforms have increased the efficacy of the system.[4–6]

ICDs have become complex and offer many programmable parameters, whether for cardiac pacing, the memory functions, or the various therapies.[7–10] Because of this technological evolution and the characteristics of devices available from a single manufacturer or among various manufacturers, the acquisition of knowledge is constantly changing. A physician should probably take advantage of every possible source of assistance,

Funding Support: None.
Financial Disclosures or Conflicts of Interest: The authors have nothing to disclose.
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Card Electrophysiol Clin 6 (2014) 207–216
http://dx.doi.org/10.1016/j.ccep.2014.02.009
1877-9182/14/$ – see front matter

including review of the technical manual of the device and contacting the manufacturer for help. It is, nevertheless, indispensable for them to be thoroughly familiar with the nuances of each model to confirm or dispute the diagnosis made by the ICD regarding a stored event, as well as, perhaps, reprogram the parameters with a view to adapting them specifically to the characteristics of individual device recipients. A systematic approach is essential for correctly identifying the cause of suspected defibrillator malfunction. Patients may present with excessive or inadequate device therapy or in contrast with insufficient therapy, with a single or multiple ICD discharges, syncope with no perceived ICD therapy, ICD therapies without previous symptoms. By a careful evaluation of the clinical history, physical examination, and radiographic techniques and then a comprehensive analysis of the stored electrograms (EGMs) and of the information obtained by telemetry (including battery voltage, charge time, function and appearance of the lead system, pacing parameters assessment), the cause of malfunction can often be determined.

In this article, a stepwise approach is presented to the most common troubleshooting cases encountered in an ICD clinic, focusing on the several multiple stages that lead to the final diagnosis, with a solution to the problem posed.

SYSTEMATIC OVERSENSING OF A PHYSIOLOGIC CARDIAC SIGNAL

The systematic oversensing of a physiologic cardiac signal at each cycle (oversensing of the T-wave, oversensing of the P-wave, and double counting of the R-wave) results in 2 signals with different morphologies alternating between 2 intervals (1 short, 1 long).

Patient 1: T-Wave Oversensing and Shock

A 41-year-old man suffering from hypertrophic cardiomyopathy received an Atlas (St. Jude Medical) single-chamber ICD for management of sustained ventricular tachycardia (VT). He was seen after having received an electrical shock while exercising without previous symptoms or sensation of tachycardia.

Clinical history and physical examination

Clinical assessment should systematically include the indication for implantation, activity preceding the episode, symptoms experienced during the episode, duration of the episode, and information from the family or any bystander.

This episode highlights a characteristic commonly found in presence of T-wave oversensing. Inappropriate therapies often occur during exercise; effort is associated with a decrease in the R-wave and an increase in the T-wave amplitudes. The speed of the signal is also increased, which modifies the slew rate, bringing the T-wave into a bandwidth at which it is sensed as an R-wave, causing the incorrect diagnosis of ventricular fibrillation (VF). Therapies are delivered in absence of previous ill feeling. In some cases, deep breathing may reproduce oversensing (preferentially P-wave oversensing).

Chest radiography

Chest radiography can be helpful for diagnosing lead fracture, lead dislodgement, lead malposition, or loose pin connection in the header, but a normal appearance cannot exclude a lead failure.

No specific radiographic signs can be observed in cases of T-wave oversensing or double counting of the R-wave. In contrast, oversensing of the P-wave occurs preferentially when the defibrillation coil of an integrated bipolar lead (the anode of the sensing circuit is the defibrillation electrode of the right ventricular lead) is straddling the tricuspid valve. Chest radiography typically shows the tip of the ventricular lead near the tricuspid valve.

The chest radiograph was normal in this patient.

Pacing parameters

An initial and essential step in troubleshooting is to retrieve the information from the device (programmed parameters, battery and capacitor status, system data, event logs, system component testing, including sensing and pacing thresholds).

T-wave oversensing often occurs in presence of a low-amplitude R-wave, because the gain adjusts the sensitivity automatically, based on the amplitude of the sensed R-wave. In this patient, the ventricular sensing capacities were altered (R-wave 2.6 mV at rest with a probable decrease during exercise). The pacing and defibrillation impedances and the pacing thresholds were normal.

Analysis of stored EGMs

Interval plot Interval plots are available in ICDs manufactured by Medtronic and Boston Scientific but not in St. Jude Medical ICDs. As shown in another example of a patient with a Medtronic device and double counting of the R-wave (Fig. 1), the plot gives essential information in patients with oversensing of a cardiac signal. The episode plot clearly shows the characteristic short-long cycle alternation observed in presence of oversensing of a cardiac signal other than the R-wave (P-wave, T-wave, R-wave double counting) with a typical railroad track pattern. The magnitude of alternation between the 2 cycles may be smaller