Causes and Prevention of Inappropriate Implantable Cardioverter-Defibrillator Shocks

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KEYWORDS

• Implantable cardioverter-defibrillator • Inappropriate shocks • Electromagnetic interference

KEY POINTS

- Implantable cardioverter-defibrillators (ICDs) deliver inappropriate therapy with a reported incidence between 2% and 20% a year.
- Nonphysiologic sensing may be caused by external electromagnetic sources, device-related issues, or supraventricular arrhythmias.
- Electromagnetic sources reported to result in inappropriate shocks include monopolar electrosurgery used during surgery; MRI; close proximity to leaking alternating current from various sources, including power equipment and arc welding; and being exposed to an electrical stun gun.
- Device-related causes of inappropriate shocks are physiologic, such as T-wave oversensing or sensing of diaphragmatic myopotentials, or pathologic, such as oversensing of lead noise.
- Advances in ICD programming have decreased but not eliminated inappropriate shocks.

INTRODUCTION

The use of implantable cardioverter-defibrillators (ICDs) as a primary prevention therapy has been shown to reduce mortality in patients after cardiac arrest and also with left ventricular systolic dysfunction.[1] However, these devices are not without morbidity. In addition to periprocedural complications, patients are also at risk of receiving inappropriate therapies, which include inappropriate shocks and antitachycardic pacing (ATP). ICD shocks have been associated with the development of psychological disorders, poor quality of life, and increased risk of death when compared with patients who do not receive any therapy.[2] Given the morbidity and potential mortality associated with inappropriate shocks, significant advances have been made in ICD programming to minimize inappropriate therapies with the publication of several landmark trials.[3–5]

This article reviews the epidemiology and etiology of inappropriate ICD shocks, the adverse effects of ICD shocks, and strategies to minimize the risk of ICD therapies.

EPIDEMIOLOGY

The rates of inappropriate shocks reported in clinical trials are significant. In the Multicenter Automatic Defibrillator Implantation II (MADIT II) trial, 11.5% of the patients experienced an inappropriate shock, with inappropriate shocks accounting for 31.2% of all shocks during the 2-year follow-up.[6] Similar rates were found in an analysis of the Sudden Cardiac Death in Heart Failure (SCD-HeFT) trial, in which 17.4% of the patients

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Card Electrophysiol Clin ■ (2017) ■–■
https://doi.org/10.1016/j.ccep.2017.11.006

experienced inappropriate shocks during a median follow-up of 3.8 years, and inappropriate shocks accounted for at least 32.3% of all ICD shocks.[7] Even higher percentage of patients were noted have experienced inappropriate shocks in the Prophylactic Defibrillator Implantation in Patients with Nonischemic Dilated Cardiomyopathy (DEFINITE) trial, with 49 of the 229 patients (21.4%) in the ICD arm experiencing inappropriate shocks during a mean follow-up of 29 months.[8]

Rates of inappropriate shocks reported in registry and cohort studies tend to be more variable and at times markedly lower compared with incidence rates in clinical trials. A Dutch study of 1544 patients who had ICDs implanted from 1996 to 2004 found 13% of patients received inappropriate shocks during 41 months of follow-up.[9] A similar rate was found in a large US observational study of 186,000 patients, where the 5-year incidence rate of inappropriate shocks was 16%.[10] In contrast, a Danish study looking at a prospective cohort of 1609 patients with ischemic heart disease and primary prevention ICDs found an inappropriate shocks incidence rate of 2.6% during mean follow-up of 1.9 years.[11] Additionally, a retrospective multicenter study in Spain of 1012 patients also found an inappropriate shocks incidence rate of 6.8% during a mean follow-up of 2.7 years.[12] However, an analysis of the patients enrolled in Boston Scientific's remote monitoring system (LATITUDE) found that 41% of first shocks were deemed inappropriate.[13] A major limitation in assessing the trends of inappropriate shocks over time using cohort or registry data is that often these studies report a rate of inappropriate shocks over a certain time period rather than an annual rate. Heterogeneity in device programming over time may account for the wide variance in incidence rates in "real-world" studies.

The advent of the subcutaneous ICD (S-ICD) was an opportunity to obviate some of the complications associated with a transvenous ICD system (pneumothorax, lead fracture, lead perforation, lead dislodgement, and device-associated endocarditis) in eligible patients. The rates of inappropriate shocks with the S-ICD system seem to be comparable with the rates of transvenous ICD. In a large Dutch cohort of 581 patients, 8.3% of patients received inappropriate shocks during a mean follow-up of 21 months.[14] In a multicenter prospective trial assessing safety and efficacy of S-ICDs, 13.1% of patients received inappropriate shocks over a mean follow-up of 11 months.[15]

ETIOLOGIES OF INAPPROPRIATE SHOCKS

Etiologies of inappropriate shocks are conceptualized into framework consisting of three groups: (1) environmental causes leading to electromagnetic interference and inappropriate sensing of external noise, (2) device-related causes from inappropriate sensing of physiologic or pathologic signals, and (3) supraventricular arrhythmias. Environmental causes of inappropriate shocks are from inappropriate sensing of electromagnetic signals in the environment. These include monopolar electrosurgery used during surgery[16]; MRI[17]; close proximity to leaking alternating current from various sources, including power equipment (Fig. 1) and arc welding[18]; and being exposed to an electrical stun gun.[19] Device-related causes of inappropriate shocks are categorized based on the cause of inappropriate sensing: physiologic, such as T-wave oversensing (Fig. 2) or sensing of diaphragmatic myopotentials (Fig. 3); or

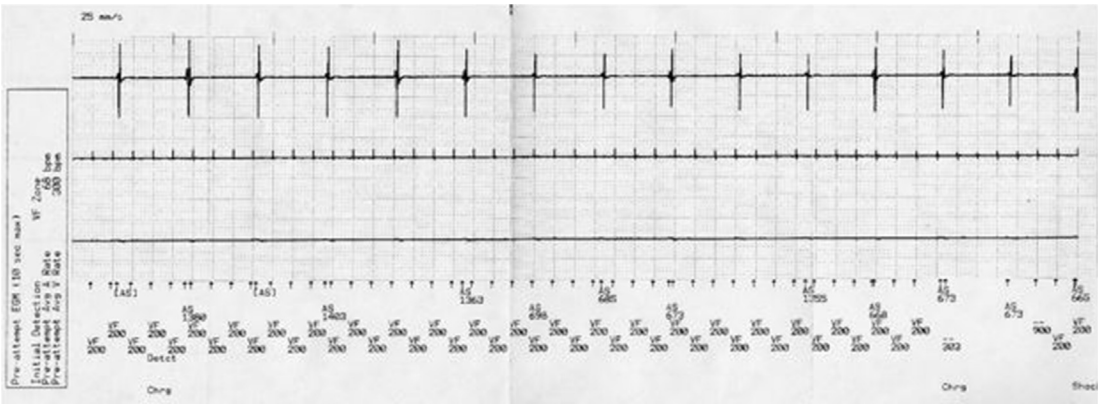

Fig. 1. A 63-year-old man with syncope while mowing the lawn. The ventricular channel senses an electrical signal from the electric lawnmower.