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ELECTROPHYSIOLOGY

CASE REPORT: CLINICAL CASE

Intra-Abdominal Hemorrhage Triggering Inappropriate Therapy From a Subcutaneous Defibrillator

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ABSTRACT

The SMART Pass filter (Boston Scientific) aims to reduce inappropriate shocks (IASs) from subcutaneous implantable cardioverter-defibrillators by filtering out low-frequency signals such as T waves. However, this filter is deactivated in the presence of diminished R-wave sensing. We describe a case of IAS in the setting of extensive intra-abdominal hemorrhage. (J Am Coll Cardiol Case Rep 2024;29:102167) Crown Copyright © 2024 Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 63-year-old man called an ambulance because he had presyncope and abdominal pain. On arrival to the emergency department, his blood pressure was 60/40 mm Hg, and his heart rate was 120 beats/min. His vital signs did not respond to a rapid infusion of 2.5 L of crystalloid, and Glasgow Coma Scale score fell from 15 to 13. His abdomen was distended, with generalized tenderness and guarding.

PAST MEDICAL HISTORY

He had diagnosis of Noonan syndrome (heterozygous pTPN11 gene sequence change) and demonstrated typical features, including pectus excavatum, characteristic facial features, and hyperextensible skin. He had coronary ectasia and underwent coronary artery bypass grafting 10 years before presentation. A transvenous implantable cardioverter-defibrillator (TV-ICD) was inserted for primary prevention of sudden cardiac death in the setting of reduced ejection fraction heart failure, but as a result of a lead fracture, he subsequently elected for a Boston Scientific Emblem A206 subcutaneous implantable cardioverter-defibrillator (S-ICD). His TV-ICD leads remain in situ.

LEARNING OBJECTIVES

- To be able to make a list of causes of automatic SP deactivation.
- To understand the role of the SP filter in reducing IASs from S-ICDs.

INVESTIGATIONS

Point-of-care blood testing showed a falling hemoglobin from 113 to 87 g/L, a lactate value of 3 mmol/L, and pH 7.31. Computed tomography (CT) with angiography revealed extensive intra-abdominal hemorrhage into all compartments of the abdomen and pelvis (Figure 1), but no active source was found on

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ABBREVIATIONS AND ACRONYMS

CT = computed tomography

IAS = inappropriate shock

OS = oversensing

S-ICD = subcutaneous implantable cardioverter-defibrillator

SP = SMART Pass

SVT = supraventricular tachycardia

TV-ICD = transvenous implantable cardioverter-defibrillator

TWOS = T-wave oversensing

mesenteric angiography. The presumed cause was spontaneous bleeding from a branch of the left colic artery. During this initial treatment phase, the patient received 2 inappropriate shocks (IASs) while lying supine, with no broad complex tachycardia recorded on telemetry. A 12-lead electrocardiogram confirmed sinus tachycardia (Figure 2), and a chest radiograph revealed clear lung fields with appropriate S-ICD positioning. Further shocks were prevented by placing a magnet over the device.

MANAGEMENT

A massive transfusion protocol was commenced, including warfarin reversal, resulting in improvement of blood pressure to 110/70 mm Hg with no clinical evidence of ongoing hemorrhage. Unfortunately, given his abdominal distention, oxygen requirements increased (fraction of inspired oxygen increased from 24% to 50%). To improve ventilation, the decision was made to perform CT-guided drainage of hemorrhage, leading to the removal of 10 L of fluid and blood over 48 hours.

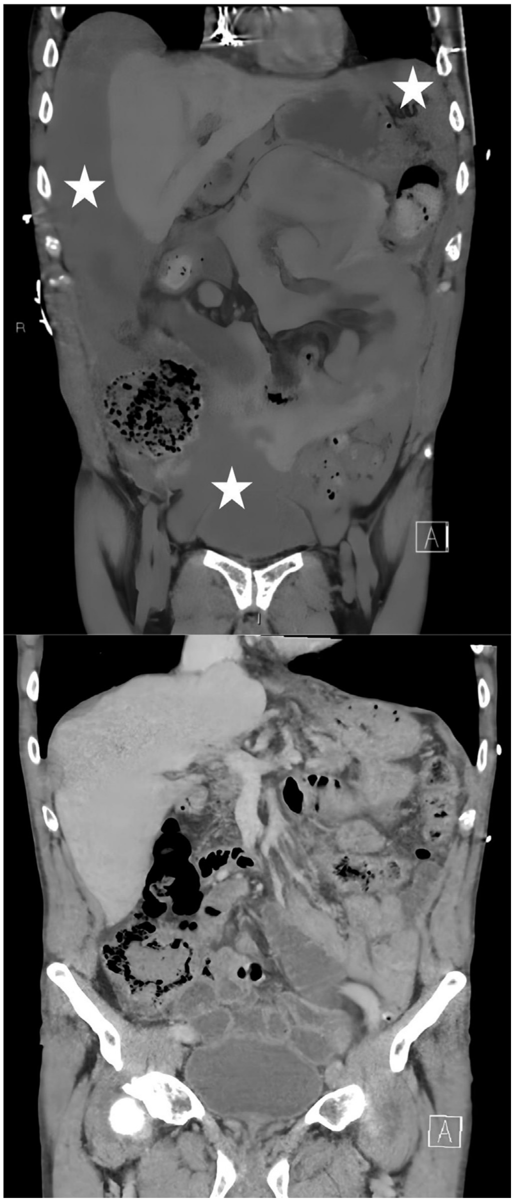
S-ICD interrogation revealed multiple IASs. A change in the sensing vector in response to the massive intra-abdominal hematoma had reduced R-wave sensing, thus resulting in automatic deactivation of the SMART Pass (SP, Boston Scientific) filter and leading to subsequent T-wave oversensing (TWOS) at the time of the IASs (Figures 3A to 3C). After drainage, SP was reactivated with new sensing templates. No further TWOS was seen.

DISCUSSION

The S-ICD is increasingly used in selected patients because of a lower risk for systemic infection, vascular injury, and pneumothorax, as well as ease of procedural implantation.[1,2] Despite preprocedural screening and advancements in device algorithms, S-ICDs have higher rates of IASs than TV-ICDs. Here, we present a unique case of a patient who experienced IASs from their S-ICD following a massive intra-abdominal hemorrhage.

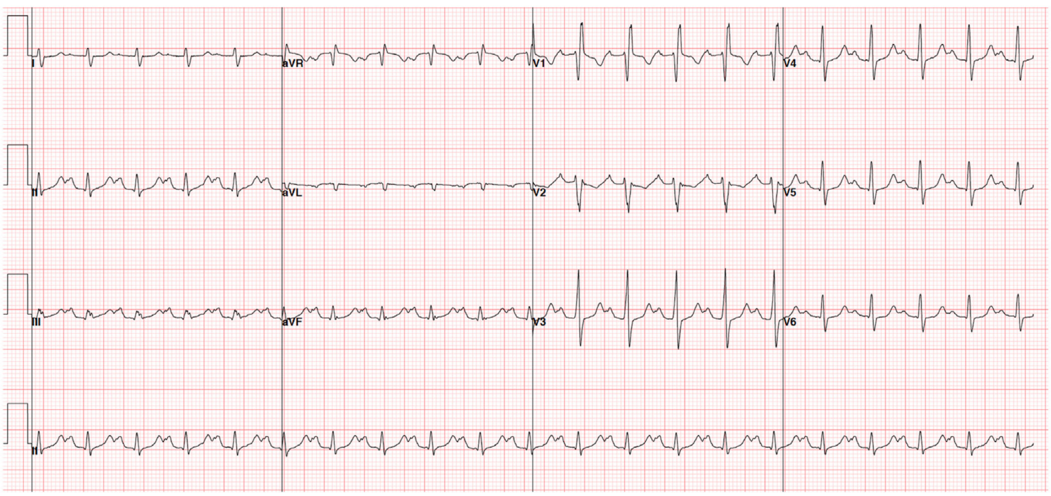
A higher incidence of IASs in S-ICDs is balanced against a lower rate of lead-related problems compared with TV-ICDs.[2,3] Later-generation S-ICDs, however, have updated programming algorithms to improve arrhythmia detection by using a high-pass filter (SP filter), thereby reducing IAS incidence from 9.7% with first-generation devices[2] to 6.0% and 2.9% with second- and third-generation devices, respectively.[4] Additionally, our understanding of clinical predictors of IASs, including the presence of atrial fibrillation,[5] hypertrophic cardiomyopathy,[5] and obesity,[6] can influence patient selection. However, IASs can still occur with S-ICDs using SP technology, as demonstrated by our unique case.

FIGURE 1 **Computed Tomography Before and After Drainage of Hemorrhage**



(Top) Predrainage computed tomography with intravenous contrast shows extensive hemorrhage (stars) in the upper quadrants that extends anteriorly to the colonic splenic flexure and inferiorly behind the jejunum and into the peritoneal cavity. (Bottom) Postdrainage noncontrast computed tomography demonstrates resolution of the hemorrhage.

FIGURE 2 12-Lead Electrocardiogram (25 mm/s, 10 mm/mV) Taken on Arrival and Showing Sinus Tachycardia (122 beats/min)



Most IASs from S-ICDs result from cardiac oversensing (OS), given their morphology-based sensing algorithm, as compared with supraventricular tachycardia (SVT), as seen in TV-ICDs.[5] S-ICDs use 3 sensing electrodes from which 3 vectors representing cardiac electrical activity can be derived. On the basis of the ratio of the QRS complex to the T-wave, 1 vector is selected as the primary configuration for sensing.[7] There is a trend toward higher rates of IAS when only 1 of 3 vectors is deemed appropriate for sensing (4.4%, 1.1%, and 1.2% for patients passing 1, 2, and 3 vectors, respectively) and when the QRS/T ratio in lead I <3.[6]

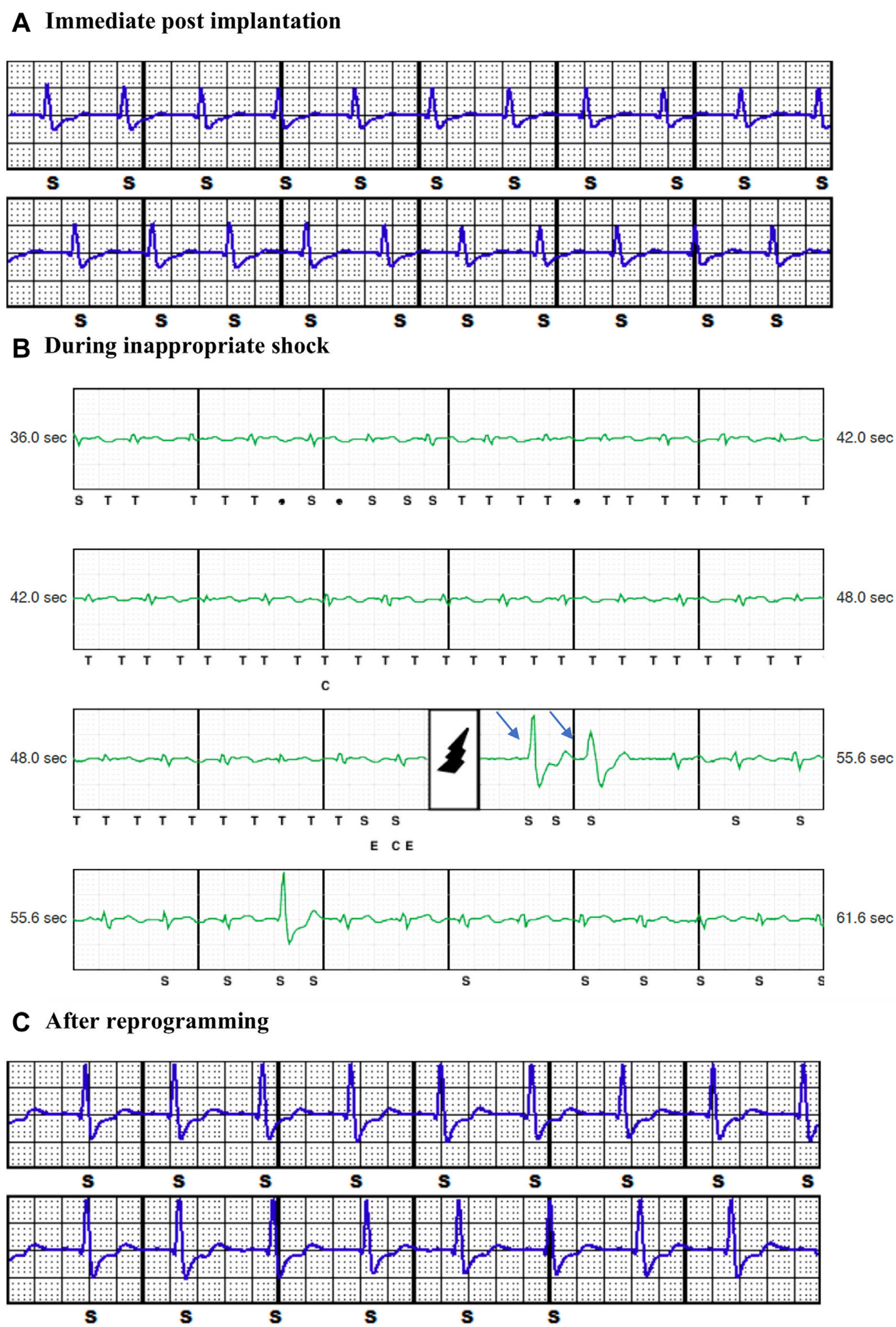
Intrinsic differences in frequencies between the QRS complex (>10 Hz) and T waves (<9 Hz) on surface and subsurface electrocardiograms have allowed for the addition of the SP filter, a first-order high-pass filter with a corner frequency between 8 and 9 Hz.[7] Reductions in OS with SP have led to reductions in IASs.[7] In the presence of low amplitude cardiac and non-cardiac signals (<0.25 mV) with two long intervals >1.4 s or due to periods of asystole (>10s), SP will automatically deactivate to avoid undersensing of low-amplitude malignant arrhythmias (eg, ventricular fibrillation). Rates of IASs, specifically due to non-cardiac OS, are 2.3% without SP, and only 0.5% with SP. Reactivation requires face-to-face device interrogation.

SP deactivation is most commonly associated with diminishing R-wave amplitude, and as a result, the 2 phenomena have become closely linked. Any process that diminishes R-wave amplitude risks automatic SP deactivation, including air in the device pocket or progression of a myopathic process such as arrhythmogenic right ventricular cardiomyopathy.[8] Other triggers include changes in QRS vectors caused by cardiac remodeling[9] or QRS configuration as a result of electrolyte abnormalities,[10] periodic changes in axis with arrhythmias such as aberrant SVT or nonsustained ventricular tachycardia, and sustained pauses.[8]

To the best of our knowledge, this is the first report of a massive intra-abdominal hemorrhage shifting the heart and leading to altered R-wave amplitude and automatic SP deactivation.

The key to managing cases of IAS is prompt recognition of non-device-related causes. Alerts for SP deactivation were incorporated into the LATITUDE (Boston Scientific) remote monitoring system in late 2022 to allow review of recordings at the time of SP deactivation to determine the trigger. Reversible causes of SP deactivation such as electrolyte imbalances or medication-induced bradycardia should be addressed swiftly followed by reactivation of SP. With sensing vector changes from arrhythmias such as aberrant SVT or the development of bundle branch block, SP can be reactivated to the new vector, or arrhythmias can be treated to prevent vector changes at the discretion of the clinician. Our case of SP deactivation from intra-abdominal hemorrhage was not immediately reversible, and in such cases, defibrillation was temporarily disabled until the trigger was addressed.[8] Once a trigger is addressed, a device

FIGURE 3 **Changes to Subcutaneous Implantable Cardioverter-Defibrillator Device Electrograms**



Observe the reduction in the sensed R-wave amplitude and an R-to-T-wave ratio from (A) approximately 5:1 at post-implantation to (B) approximately 2:1 during hemorrhage, thereby leading to automatic SMART-Pass (Boston Scientific) deactivation and T-wave oversensing followed by delivery of shock. "S" represents sensed R waves, whereas "T" represents sensed R waves that fit within the programmed shock zone (230 beats/min). Postshock ventricular ectopy (arrows) is present. (C) Following treatment, new sensing vectors were obtained, as demonstrated by larger sensed R waves and an R-to-T-wave ratio of approximately 9:1.

interrogation to establish new sensing templates and reactivate SP should be conducted.

FOLLOW-UP

A device interrogation 3-months post discharge showed good R-wave sensing and no further IASs. He had recovered well from his prolonged admission.

CONCLUSIONS

This is the first case to describe how a massive intra-abdominal hematoma can alter the S-ICD's sensing vector and lead to IASs. This report describes how reduced R-wave sensing led to SP filter deactivation and subsequent TWOS that was corrected by drainage of the hematoma.

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The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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KEY WORDS inappropriate shock, SMART Pass algorithm, subcutaneous ICD