A case of pseudo-appropriate shock

Neal J. Ferrick, MD,* John D. Fisher, MD, FHRS,† Jay N. Gross, MD, FHRS,†
Andrew K. Krumerman, MD, FHRS†

*From the *Department of Medicine, Montefiore Medical Center, Bronx, New York, and †Department of
Medicine, Division of Cardiology, Clinical Cardiac Electrophysiology, Montefiore Medical Center,
Bronx, New York.*

Introduction

Implantable cardioverter-defibrillators (ICD) have been demonstrated to improve survival in patients who have experienced aborted sudden cardiac arrest as well as for primary prophylaxis of sudden cardiac arrest in certain high-risk patients. Despite their established role in the management of patients identified as being at risk for sudden cardiac arrest, inappropriate ICD therapy remains problematic and has been associated with increased cardiovascular mortality. The majority of inappropriate ICD therapy results from either the detection of a variety of supraventricular arrhythmias, T-wave oversensing, or lead failure with concomitant detection of noise. Inappropriate shocks can be associated with increased morbidity and mortality. Ventricular proarrhythmia related to inappropriate therapy has also been reported. We report a case where inappropriate therapy was delivered for an appropriate rhythm (ventricular tachycardia; VT) in a patient with a subcutaneous ICD. This might be termed "pseudo-appropriate therapy."

Case report

The patient is a 38-year-old woman with a history of infundibular pulmonic stenosis who is status post pulmonary valve surgery and septal patch repair. Concomitant history includes previous treatment for infective endocarditis and septic emboli resulting in a right middle lobe lobectomy and subsequent bioprosthetic valve replacement. In 2014, she presented with sustained VT at an outside hospital, and underwent placement of a first-generation Boston Scientific subcutaneous ICD, in an attempt to mitigate subsequent infective risk. Evidence of electrocardiogram screening prior to implantation was not available for review. Initial ICD programming was set in the secondary sensing configuration, with a Gain of 2X, and SMART charging set at 5 intervals.

Address reprint requests and correspondence: Dr Neal J. Ferrick, Department of Medicine, Montefiore Medical Center, 111 E. 210th St, Bronx, NY 10467. E-mail address: nferrick@montefiore.org.

KEY TEACHING POINTS

- Subcutaneous implantable cardioverter-defibrillator (ICD) placement is usually reserved for patients with increased risk of infection, those with complicated lead extraction, and those not requiring ventricular pacing.
- Subcutaneous ICDs have an increased risk of QRS double counting and T-wave oversensing.
- Subcutaneous ICD devices have dual programming based on heart rate alone (primary) and algorithmic (conditional), based on morphology.
- The lowest threshold for programming is at a rate of 170 beats/min, making it difficult to control slow ventricular tachycardia.

Following ICD implantation, the patient underwent electrophysiologic study and catheter ablation for recurrent VT that was believed to be related to a ventriculotomy scar. Subsequently, she experienced recurrent VT and underwent repeat radiofrequency catheter ablation utilizing Impella support. Therapy with sotalol was initiated; however, she continued to experience recurrent VT and required adjunctive mexiletine therapy. During a third electrophysiologic study, VT was induced, and subcutaneous ICD sensing was tested. QRS double counting was noted in both secondary and alternative configurations; however, no double counting was noted with the primary configuration. Her ICD was set in the primary sensing configuration.

Despite adherence to her medical regimen, she presented to our institution complaining of an ICD shock. Initial electrocardiogram screening showed first-degree atrioventricular block, with an incomplete right bundle branch block pattern (Figure 1). Device interrogation demonstrated sensing set in primary configuration with an episode of VT at a rate of 140 beats per minute, for which she underwent shock therapy despite a programmed VT detection rate of 190 beats per minute; the ventricular fibrillation zone was programmed to 240 beats per minute. Analysis of ICD electrograms
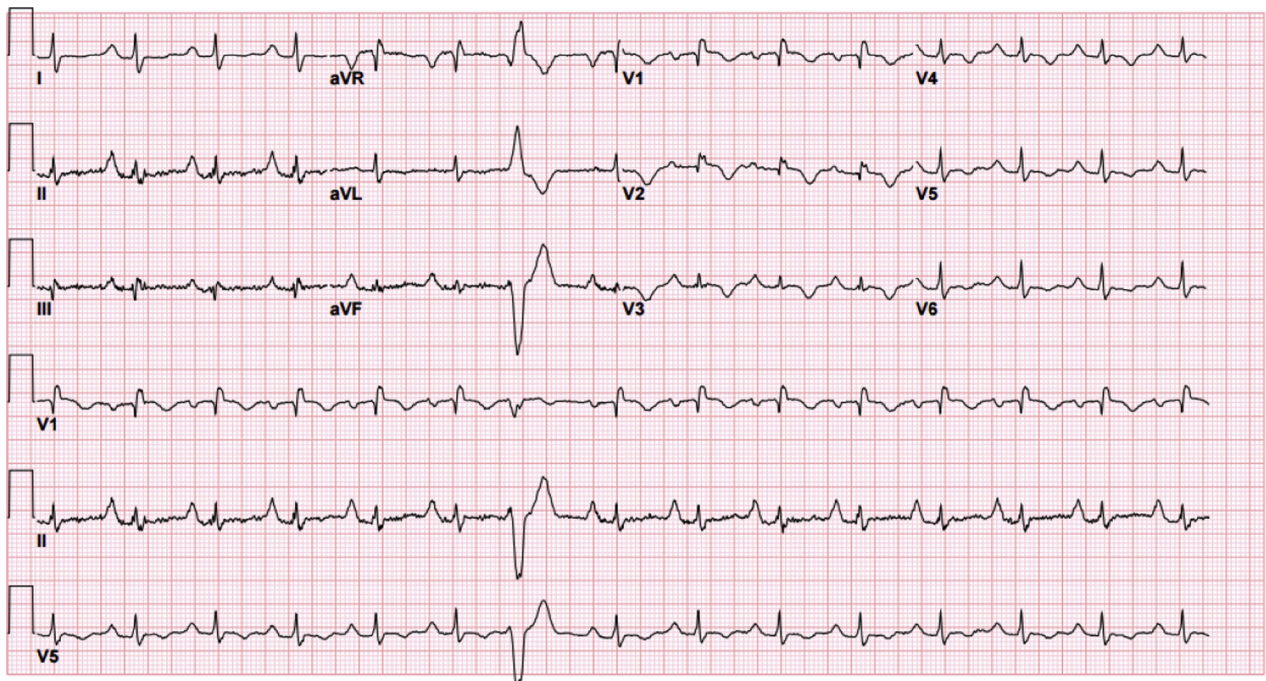
Figure 1   Initial electrocardiogram recorded at our institution. Image shows that the patient is in first-degree atrioventricular block, with an incomplete right bundle branch block pattern and possible biatrial enlargement. Also noted is a premature ventricular contraction on the recording.

demonstrated "double counting" of the QRS complex, which was extremely wide. Although the tachycardia was appropriately terminated, the patient was shocked while awake and hemodynamically stable. She ultimately underwent repeat ablation, which demonstrated VT with an epicardial origin. VT was noninducible post ablation. Reprogramming of the sensing vector of her subcutaneous ICD in an attempt to alter the detected QRS duration and maximize electrogram amplitude in an attempt to minimize enhanced gain also was performed.

Discussion

Despite demonstrated efficacy in identifying and terminating ventricular tachyarrhythmias, device-based therapy for patients at risk of sudden cardiac arrest has multiple limitations. Although ICD therapy has been demonstrated to reduce mortality in patients who have experienced out-of-hospital cardiac arrest as well as for patients with ischemic cardiomyopathy and left ventricular dysfunction, the role of ICD therapy for the management of the at-risk patient with nonischemic cardiomyopathy has been called into question by the recently published DANISH trial.[1] This study failed to demonstrate a statistically significant increase in survival in patients with nonischemic cardiomyopathy. Other studies have demonstrated that the survival of patients receiving ICD shock therapy is reduced when compared with individuals who do not receive ICD shocks.[2] As such, current-generation devices are often programmed to minimize ICD shock therapy. Such interventions include enhancing aggressive antitachycardia pacing therapy, prolonging the delay from VT detection to the therapy initiation (in an attempt to

minimize therapy for self-terminating arrhythmias), and programming high VT detection rates.

Our patient, despite aggressive therapy, received shock therapy for a slow well-tolerated VT. Although in one sense such therapy was "appropriate," it could indeed be considered "inappropriate" insofar as the therapy was rendered for a tachycardia well below the tachycardia detection rates. The EFFORTLESS Study, an observational, nonrandomized, standard-of-care study, demonstrated that with the subcutaneous ICD, 8.1% of the population experienced inappropriate shocks in the first year. This increased to 11.7% over an average 3.1 years of follow-up. Of these inappropriate shocks, 7.7% received a shock mainly owing to T-wave oversensing or low-amplitude signals.[3] It has been previously noted that oversensing of the T wave or myopotential signals are the most common cause for inappropriate ICD shocks. This was likely due to the single defibrillation detection zone created for the subcutaneous ICD. To try and remedy the problem of T-wave oversensing and inappropriate shocks, new algorithms were developed. These algorithms added a conditional shock zone, set at a lower heart rate threshold, where the ICD would analyze the rhythm and deliver appropriate therapy.[4] After the initiation of the conditional shock zone, there was a noted decrease in inappropriate shocks.[5] With dual-zone programming, the initial detection zone analyzes the rhythm based on heart rate only, while the conditional zone uses morphology analysis to determine whether the rhythm is a shockable vs a nonshockable rhythm.[6] Additional tools for preventing inappropriate shocks include sensing optimization and template creation during exercise.[7]
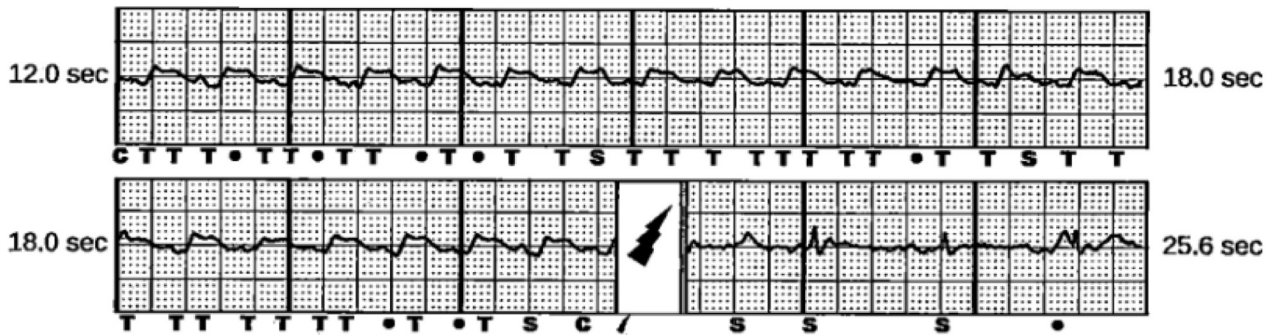
Figure 2 Tracings from the interrogation of the patient's device, while set to the secondary sensing vector. Ventricular tachycardia (VT) at a rate of 140 with double counting of QRS complexes is noted (marked "T"). The lightning bolt represents shock delivery and is followed by termination of VT.

In our case, double counting of QRS complexes, rather than T-wave oversensing in the nonconditional zone, resulted in an inappropriate shock (Figure 2). Others have reported incidents where double counting of QRS complexes has led to inappropriate shocks in the setting of hyperkalemia.[8,9] Our patient had a normal potassium level when QRS complexes were double counted. Effective management was compromised by the limited programmability of the subcutaneous device in terms of sensitivity adjustment as well as the inability of the device to provide antitachycardia pacing.

Younger patients, or those with an increased risk of infection and complicated cardiac anatomy, may benefit from a subcutaneous implant rather than transvenous ICD, owing to a reduced long-term risk of infection.[10] Ideally, patients who would be at risk of transvenous ICD lead complications, who do not require ventricular pacing, are candidates for a subcutaneous ICD. Other factors that would influence placement of a subcutaneous ICD rather than a transvenous ICD include patients with significant renal disease, to preserve venous access for potential dialysis candidates.[7] In patients with slow VT, although short lasting, studies have shown that antitachycardia pacing has been shown to efficiently terminate VT. However, antitachycardia pacing is not available in subcutaneous ICDs; in fact, the minimum rate at which a subcutaneous ICD can be programmed is 170 beats/min. In patients with slow VT, either ablative therapy should be considered; if continued,

transvenous ICD placement might be more beneficial. However, most slow VT does not lead to life-threatening situations.[7,11] In this case, the decision to implant a subcutaneous device was predicated in part by a history of endocarditis as well as the presence of a prosthetic cardiac valve. Given this patient's baseline bundle branch block, preoperative screening measures should have been performed to determine whether double counting of a wide QRS complex would result in inappropriate detection.[12] Ultimately, inappropriate detection of a slower VT with double counting led to an appropriate therapy, terminating tachycardia (Figure 3). In order to avoid therapy during episodes of slow hemodynamically tolerated VT, sensing vectors can be analyzed during VT during electrophysiologic study. Our attempts to optimize sensing during electrophysiologic study ultimately were not successful, and catheter ablation was successfully performed.

Conclusion

In conclusion, this case illustrates a difficult dilemma encountered when patients with subcutaneous ICDs develop slow VT. QRS double counting during VT resulted in inappropriate therapy. However, owing to the fact that the patient was in VT (a shockable rhythm below the tachycardia detection rate), the inappropriate shock due to QRS double counting can be seen as appropriate or "pseudo-appropriate."
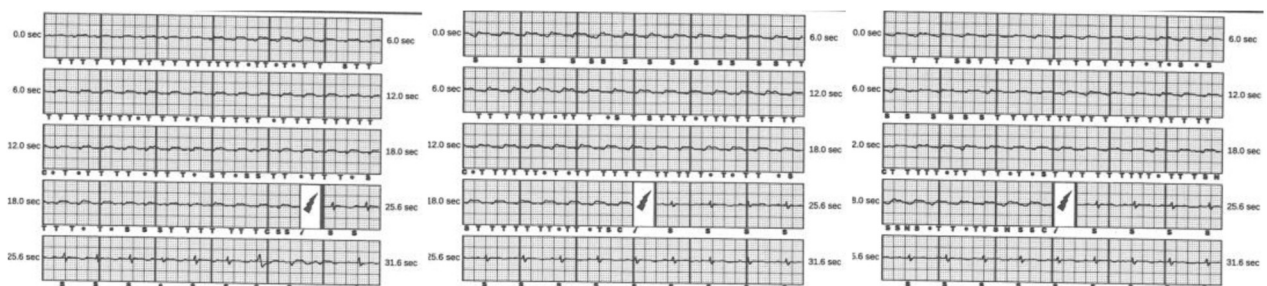

Figure 3 Tracings from interrogation of the patient's device on 3 separate instances, where the patient received shocks. In all 3 cases the patient was in ventricular tachycardia (VT). Sensing is noted in the primary sensing configuration and sensing the rhythm (marked "S"); however, the rate is below the programmed VT detection rate of 190 beats per minute. Oversensing is noted and a shock is delivered.

References

1. Køber L, Thune J, Nielsen J, et al. Defibrillator implantation in patients with nonischemic systolic heart failure. N Engl J Med 2016;375:1221–1230. https://doi.org/10.1056/nejmoa1608029.

2. Powell BD, Saxon LA, Boehmer JP, et al. Survival after shock therapy in implantable cardioverter-defibrillator and cardiac resynchronization therapy-defibrillator recipients according to rhythm shocked. J Am Coll Cardiol 2013;62:1674–1679. https://doi.org/10.1016/j.jacc.2013.04.083.

3. Boersma L, Barr C, Knops R, et al. Implant and midterm outcomes of the subcutaneous implantable cardioverter-defibrillator registry. J Am Coll Cardiol 2017;70:830–841. https://doi.org/10.1016/j.jacc.2017.06.040.

4. Afzal MR, Evenson C, Badin A, et al. Role of exercise electrocardiogram to screen for T-wave oversensing after implantation of subcutaneous implantable cardioverter-defibrillator. Heart Rhythm 2017;14:1436–1439.

5. Aziz S, Leon AR, El-Chami MF. The subcutaneous defibrillator. J Am Coll Cardiol 2014;63:1473–1479.

6. Gold MR, Weiss R, Theuns DAMJ, et al. Use of discrimination algorithm to reduce inappropriate shocks with a subcutaneous implantable cardioverter-defibrillator. Heart Rhythm 2014;11:1352–1358.

7. Willcox ME, Prutkin JM, Bardy GH. Recent developments in the subcutaneous ICD. Trends Cardiovasc Med 2016;26:526–535.

8. Dadlani A, Dukes JW, Badhwar N. Inappropriate implantable cardioverter-defibrillator shock from QRS double counting in the setting of hyperkalemia. Card Electrophysiol Clin 2016;8:177–179. https://doi.org/10.1016/j.ccep.2015.10.024.

9. Faustino M, Madeira F, Morais C. An inappropriate defibrillator shock during ventricular tachycardia. Indian Pacing Electrophysiol J 2015;15:184–187. https://doi.org/10.1016/j.ipej.2015.10.002.

10. Gold MR, Aasbo JD, El-Chami MF, et al. Subcutaneous implantable cardioverter-defibrillator post-approval study: clinical characteristics and perioperative results. Heart Rhythm 2017;14:1456–1463. https://doi.org/10.1016/j.hrthm.2017.05.016.

11. Sadoul N, Mletzko R, Anselme F, et al. Incidence and clinical relevance of slow ventricular tachycardia in implantable cardioverter-defibrillator recipients: an international multicenter prospective study. Circulation 2005; 112:946–953.

12. Tachibana M, Nishii N, Morimoto Y, et al. Complete right bundle branch block and QRS-T discordance can be the initial clue to detect S-ICD ineligibility. J Cardiol 2017;70:23–28.