

Inappropriate shocks by subcutaneous implantable cardioverter-defibrillator due to T-wave oversensing in hyperkalemia leading to ventricular fibrillation



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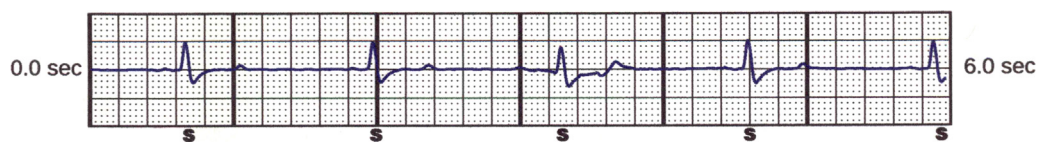


Figure 1 Surface electrocardiogram from the subcutaneous implantable cardioverter-defibrillator demonstrating appropriate QRS-T complex discrimination during implantation and normokalemia.

Introduction

The implantable cardioverter-defibrillator (ICD) has reduced mortality in survivors of sudden cardiac arrest and patients at high risk of sudden cardiac death.¹ This benefit comes at the cost of device-related complications, including those related to transvenous leads.² The subcutaneous ICD (S-ICD) is an alternative to the conventional transvenous ICD (TV-ICD) system and has no transvenous leads, thereby avoiding endocardial lead-related complications.² However, with only subcutaneous electrodes, rhythm detection and discrimination is a much more challenging task for the S-ICD. We describe a case of ventricular fibrillation induced by inappropriate shocks from the S-ICD owing to T-wave oversensing (TWOS) in the setting of hyperkalemia and dialysis-dependent chronic renal failure.

Case report

A 33-year-old man with a history of dilated cardiomyopathy with reduced left ventricular ejection fraction (25%) and end-stage renal disease requiring intermittent hemodialysis was resuscitated in the community after experiencing rapid monomorphic ventricular tachycardia with syncope. He

received a single-chamber TV-ICD (Protecta XT VR; Medtronic, Minneapolis, MN) for secondary prevention prior to hospital discharge. During the patient's routine assessments in the device clinic, intermittent TWOS was noted, but in each instance it had been appropriately discriminated by the TWOS algorithms of the device and no inappropriate therapies had been delivered. In follow-up, the patient developed a persistent coagulase-negative *Staphylococcus* bacteremia, which ultimately required the removal of the ICD system 13 months after the original implant.

The patient required a chronic indwelling catheter for hemodialysis; therefore, to mitigate risk of future infection following resolution of the patient's bacteremia, the patient received an S-ICD device implantation (SQ-RX Pulse Generator Model 1010 and Q-TRAK Subcutaneous Electrode Model 3010; Cameron Health/Boston Scientific, San Clemente, CA). The generator was placed at the cardiac apex/anterior axillary line and the subcutaneous electrode along the right sternal border. There was good QRS-T complex discrimination at implantation (Figure 1) and defibrillation threshold testing was successful with reverse polarity at 80 joules.

Approximately 1 month after S-ICD placement, the patient presented to hospital with complaints of multiple, unprovoked device shocks. He reported missing 2 consecutive dialysis treatments and his serum potassium was found to be elevated at 7.0 mmol/L. Interrogation of the S-ICD revealed 5 episodes of tachycardia and 17 shocks delivered. Rhythm analysis showed that each reported episode of tachycardia was due to TWOS. During the first 3 episodes, between 3 and 5 inappropriate shocks were delivered during sinus rhythm. During the fourth and fifth episodes, the inappropriate shocks were delivered on the T-wave and

KEYWORDS Defibrillators; implantable; Subcutaneous ICD; ICD sensing; Cardiac arrest; Ventricular arrhythmias

ABBREVIATIONS ICD = implantable cardioverter-defibrillator; S-ICD = subcutaneous implantable cardioverter-defibrillator; TV-ICD = transvenous implantable cardioverter-defibrillator; TWOS = T-wave oversensing (Heart Rhythm Case Reports 2015;1:257–259)

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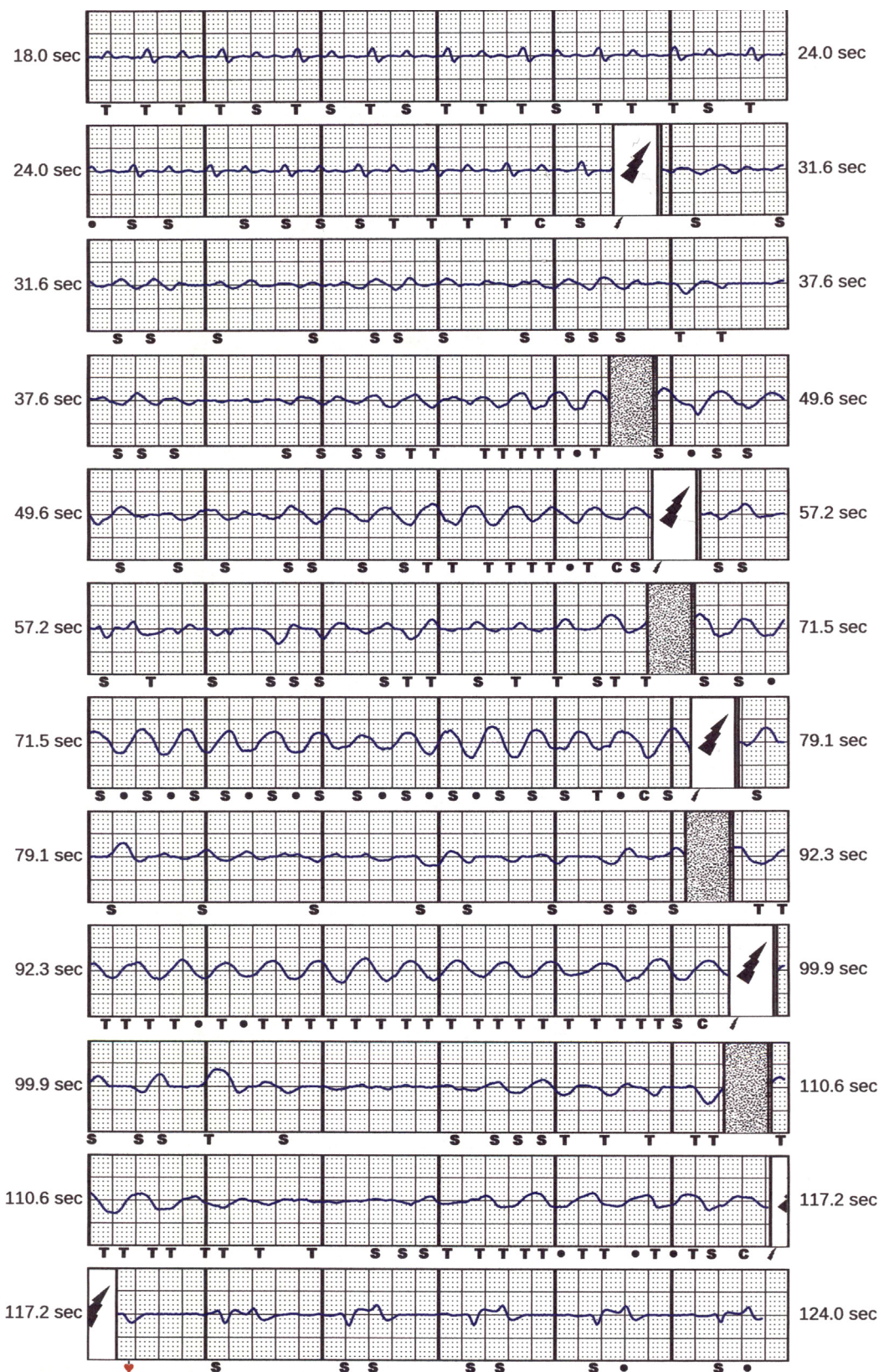


Figure 2 Surface electrocardiogram from the subcutaneous implantable cardioverter-defibrillator demonstrating inappropriate shocks due to T-wave oversensing in the setting of hyperkalemia (serum potassium 7.0 mmol/L), leading to sustained ventricular fibrillation requiring 4 shocks prior to termination.

KEY TEACHING POINTS

- The most frequent complication of the subcutaneous implantable cardioverter-defibrillator (S-ICD) is inappropriate shocks. In contrast to transvenous ICDs, inappropriate shocks from S-ICDs are often due to T-wave oversensing.
- T-wave oversensing by the S-ICD may occur in the context of hyperkalemia.
- The population in which there may be a preference for an S-ICD may also be at the greatest risk of the limitations of rhythm detection and discrimination.

induced nonsustained polymorphic ventricular tachycardia and ventricular fibrillation, respectively (Figure 2). The ventricular fibrillation lasted approximately 87 seconds and required 4 shocks before the patient returned to normal sinus rhythm. Urgent hemodialysis was initiated for correction of hyperkalemia and no further shocks occurred. The conditional shock zone and shock zone were increased to 200 and 230 beats per minute, respectively. Compliance with dialysis was recommended and the patient was discharged with clinical follow-up.

Discussion

The S-ICD system is a novel technology that offers a less invasive alternative to the conventional TV-ICD system.² Preference may be given to the S-ICD in patients for whom there is a desire to avoid the complications associated with intracardiac leads. These patients may include the young, those with poor vascular access, and those at high risk of bacteremia, such as patients with chronic indwelling endovascular catheters or those receiving hemodialysis. However, long-term safety data for the S-ICD are lacking in these complex patients.

The most frequent complication of the S-ICD is inappropriate shocks.^{3,4} While inappropriate shocks from TV-ICDs are most often due to supraventricular arrhythmias,

inappropriate shocks from S-ICDs are most often due to oversensing of T-waves and low-amplitude cardiac signals.²

Transient hyperkalemia is common in dialysis patients, a population that is difficult to manage and in which an S-ICD might be more likely to be considered owing to a decreased risk of infection. Unfortunately, hyperkalemia represents one mechanism that may lead to TWOS in the S-ICD. Increased extracellular potassium concentrations may decrease the amplitude of the QRS complex and increase the amplitude of the T-wave. Hyperkalemia may also increase defibrillation thresholds.⁵ In this case, the impaired ability of the S-ICD to discriminate the QRS-T complex led to the induction of ventricular fibrillation after a shock was delivered on the T-wave. The patient required 4 shocks at maximum device outputs to terminate ventricular fibrillation.

Conclusion

The population in which there may be a preference for an S-ICD may also be the population most at risk of the limitations of this technology. Further enhancement of the rhythm detection/discrimination abilities of these devices will significantly enhance their clinical utility. Higher defibrillation safety margins at implantation may also be warranted. To our knowledge, this is the first report of TWOS in the setting of hyperkalemia leading to inappropriate shocks from an S-ICD, resulting in sustained ventricular fibrillation.

References

1. Ezekowitz JA, Armstrong PW, McAlister FA. Implantable cardioverter defibrillators in primary and secondary prevention: a systematic review of randomized, controlled trials. *Ann Intern Med* 2003;138:445–452.
2. Bardy GH, Smith WM, Hood MA, et al. An entirely subcutaneous implantable cardioverter-defibrillator. *N Engl J Med* 2010;363:36–44.
3. Weiss R, Knight BP, Gold MR, Leon AR, Herre JM, Hood M, Rashtian M, Kremers M, Crozier I, Lee KL, Smith W, Burke MC. Safety and efficacy of a totally subcutaneous implantable-cardioverter defibrillator. *Circulation* 2013;128:944–953.
4. Lambiase PD, Barr C, Theuns DA, et al. Worldwide experience with a totally subcutaneous implantable defibrillator: early results from the EFFORTLESS S-ICD Registry. *Eur Heart J* 2014;35:1657–1665.
5. Sims JJ, Miller AW, Ujhelyi MR. Regional hyperkalemia increases ventricular defibrillation energy requirements. *J Cardiovasc Electrophysiol* 2000;11:634–641.