Nothing inside the heart – Combining epicardial pacing with the S-ICD

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Introduction

The implantation of implantable cardioverter-defibrillator (ICD) systems in patients with no or limited venous access is technically challenging. After disappointing experiences with epicardial ICD patches,[1,2] surgical techniques focused on the implantation of subcutaneous high-voltage array electrodes or intrapericardial placement of standard transvenous ICD leads.[3–6] The Boston Scientific subcutaneous ICD (Boston Scientific, Marlborough, MA) is the first completely subcutaneous ICD (S-ICD), initially approved in Europe in 2009 and market released in the United States in 2012. The S-ICD is an effective and attractive alternative to transvenous ICD systems in patients without need for antitachycardia or antibradycardia pacing.[7,8] Previous trials excluded patients with existing epicardial defibrillation patches or coils, presence of epicardial pacing leads, unipolar pacemaker systems, or documented monomorphic ventricular tachycardia likely to be terminated by antitachycardia pacing.[8,9] Therefore the safety and feasibility of S-ICD systems in patients with a concomitant epicardial pacing system and a class I indication for antibradycardia pacing is unknown.

We report a case of a patient with an indication for both a secondary prevention ICD and permanent pacing who was high risk for recurrent bacterial seeding of a transvenous device and who underwent successful implantation of an epicardial pacemaker and a Boston Scientific S-ICD system.

KEYWORDS ICD; S-ICD; Epicardial pacemaker; Limited venous access; Device interaction; Recurrent device infection; Sensing screening

ABBREVIATIONS bpm = beats per minute; **DFT** = defibrillation threshold; **ICD** = implantable cardioverter-defibrillator; **MRSA** = methicillin-resistant *Staphylococcus aureus*; **S-ICD** = subcutaneous ICD; **VF** = ventricular fibrillation (Heart Rhythm Case Reports 2015;1:419–423)

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Case report

A 78-year-old man presented with recurrent sepsis and bacteremia caused by methicillin-resistant *Staphylococcus aureus* (MRSA). His past medical history was significant for a dual-chamber ICD (Medtronic Protecta XT) implanted 3 years prior for polymorphic ventricular tachycardia with appropriate shocks during follow-up. The patient also had complicated type II diabetes with vascular involvement including chronic bilateral diabetic feet.

Before the patient came to our attention he had experienced 2 years of recurrent episodes of MRSA bacteremia necessitating prolonged courses of intravenous antibiotics adding up to a total of 12 months intravenous therapy with vancomycin and clindamycin. Blood cultures on admission at our center were again positive for MRSA, with extensive resistance to antibiotics including vancomycin. The soft tissues around the ICD pocket were unremarkable. A transesophageal echocardiogram demonstrated a 10 mm vegetation attached to one of the device leads at the atrial level without evidence of any direct valvular involvement. A previously undiagnosed chronic osteomyelitis of the left great toe was found to be the source for the patient's recurrent bacteremia and a number of his other toes had healing diabetic ulcers. An amputation of the patient's left great toe was performed prior to the extraction of his ICD system. Concomitant antibiotics consisting of intravenous daptomycin and oral trimethoprim/sulfamethoxazole were administered over a total of 6 weeks after ICD extraction.

Because of his recurrent intravascular infections and significant risk of future bacteremia, we evaluated the option of a total extravascular pacemaker and ICD system. Antibradycardia pacing was required because of underlying 2:1 atrioventricular block.

Procedure

A dual-chamber bipolar epicardial pacemaker system was implanted using the right atrium and right ventricle via a right minithoracotomy (Figure 1A). The 2 epicardial leads (Medtronic 4968 CapSure Epi, 35 cm for atrial and ventricular lead; Medtronic, Minneapolis, MN) were subcutaneously tunneled to an epigastric pulse generator

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KEY TEACHING POINTS

- Combination of epicardial pacemaker system and subcutaneous implantable cardioverter-defibrillator (S-ICD) is an alternative and safe device option in patients with limited or absent venous access.
- Complex interaction between both devices exhibits potential for double counting and inappropriate shocks through S-ICD and requires a very careful sensing screening and programming.
- Close follow-up and frequent check for oversensing through the S-ICD is mandatory.

(ALTRUA; Boston Scientific, Marlborough, MA). Both atrial electrodes were placed on the right atrial free wall. One ventricular electrode was placed on the inferior surface and 1 on the anterior surface of the right ventricle owing to extensive adipose accumulation on the right ventricle and difficulty finding adequate muscle to attach the leads (Figure 1B).

Screening for S-ICD sensing with a standard left parasternal lead position failed because only paced beats but not intrinsic beats were adequately detected in any vector configuration. Right parasternal screening showed adequate sensing parameters for intrinsic and paced beats in the primary (B to can) and secondary (A to can) vector configuration. The S-ICD was finally implanted on the left side of the thorax and the ICD lead was placed along the right parasternal border (Figure 1B).

During implantation we observed double counting of the epicardial atrial pacing through the S-ICD. At higher atrial pacing output (3.5 V/0.4 ms) the S-ICD detected atrial pacing in the secondary sensing vector (Figure 2A) but not in the primary sensing vector (Figure 2C). Lowering of the atrial pacing output to 1.5 V/0.4 ms eliminated double counting through the S-ICD (Figure 2B) at nominal sensitivity settings of the S-ICD.

Device settings and testing of defibrillation threshold

The right ventricular pacing threshold was 1.7 V at 0.5 ms and the epicardial R-wave amplitude was measured at 3.9 mV through the dual-chamber pacemaker.

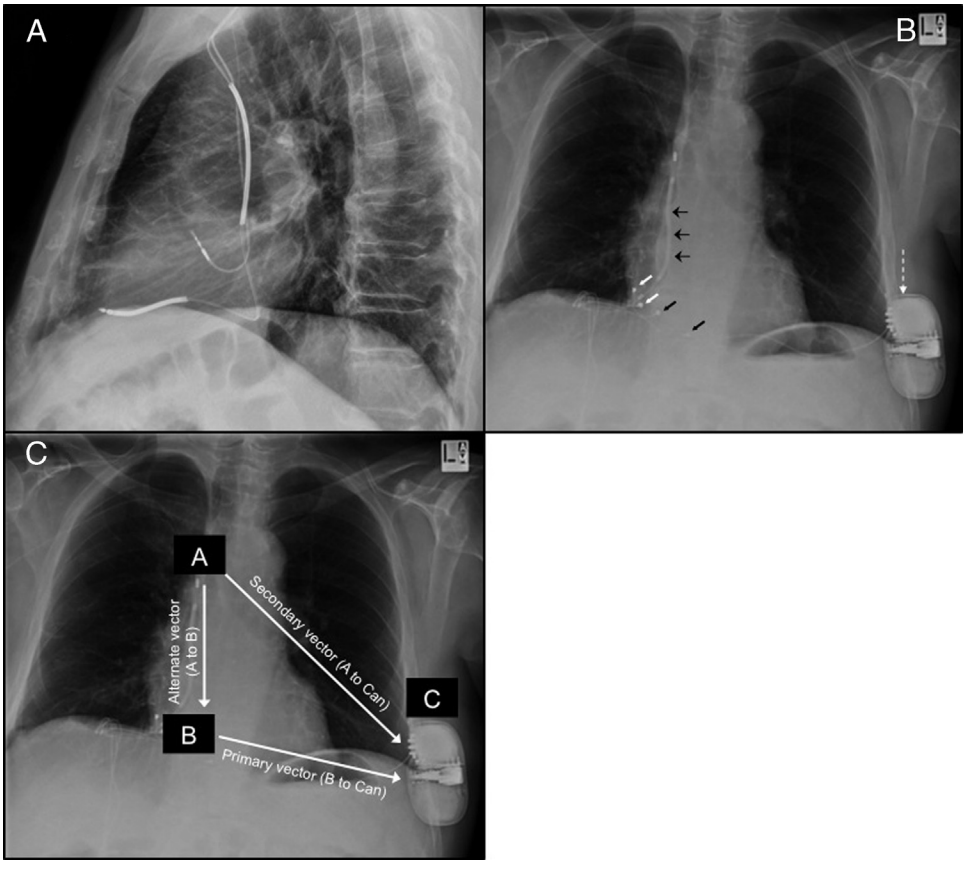

Figure 1 Chest radiographs before and after implantation of subcutaneous implantable cardioverter-defibrillator (S-ICD) and permanent epicardial pacemaker. **A:** Lateral chest radiograph of the transvenous dual-chamber ICD system prior to extraction. **B:** Posterior-anterior chest radiograph post implantation of S-ICD and permanent epicardial pacemaker. The 2 epicardial atrial electrodes are fixed to the free wall of the right atrium (*bold white arrows*). The 2 ventricular electrodes of the epicardial pacemaker are fixed to the inferior and anterior surface of the right ventricle, respectively (*bold black arrows*). The can of the S-ICD is positioned in a subcutaneous pocket at the lower left-lateral thorax (*dashed white arrow*). The S-ICD lead is placed in a right parasternal position (*black arrowheads*). **C:** Shown are the 3 bipolar sensing vectors of an S-ICD. The primary vector senses between the proximal lead electrode and the can. The secondary vector senses between the distal lead electrode and the can. The alternate vector senses between the 2 lead electrodes.

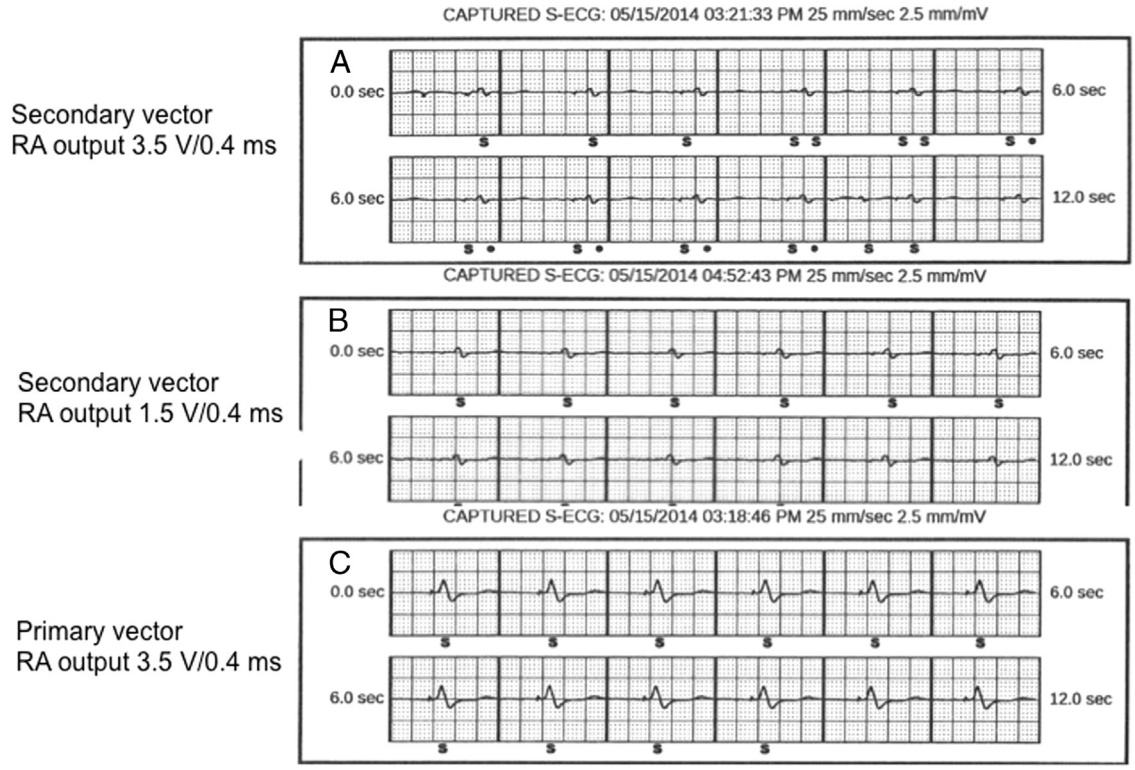

Figure 2 Sensing findings at implantation of the subcutaneous implantable cardioverter-defibrillator (S-ICD). **A:** Higher atrial pacing output (3.5 V/0.4 ms) by the epicardial pacemaker resulted in detection of atrial pacing and double counting through the S-ICD in the secondary sensing vector, but not in the primary sensing vector **(C). B:** Lowering of the atrial pacing output to 1.5 V/0.4 ms eliminated double counting through the S-ICD in the secondary sensing vector.

The upper tracking and sensor rates of the pacemaker were set to 100 beats per minute (bpm) and the trigger rate for shock delivery through the S-ICD was set to 220 bpm. The pacing output for the right ventricle and atrium during defibrillation threshold (DFT) testing was set to 5 V and 3.5 V, respectively.

Ventricular fibrillation (VF) was induced via a 50 Hz burst. The dual-chamber epicardial pacemaker failed to detect the 50 Hz burst (Figure 3A), but correctly sensed the induced VF (Figure 3B). The first 3 VF inductions were successful, but VF terminated spontaneously before the S-ICD could deliver a shock (Figure 3B). Subsequently VF was not inducible any longer. All episodes of VF were appropriately sensed by the S-ICD.

Discussion

The S-ICD is now increasingly being implanted worldwide and clinical experience reveals that the S-ICD system is a reliable and effective alternative compared to standard transvenous ICD systems.[8,10] However, there are only limited data on patients with concomitant transvenous pacemakers systems.[8,11] For example, in the EFFORTLESS registry, only 3% of all patients had a transvenous pacemaker system in addition to the S-ICD and none of them had an epicardial pacemaker.

Our report demonstrates the feasibility of the co-implantation of an S-ICD system with a permanent epicardial pacemaker, which exhibits several unique and challenging elements.

As mentioned before, a total extravascular device system was chosen for our patient because of the high risk of recurrent device infection. Although the rates of pocket infection in S-ICDs are currently still higher compared to standard transvenous ICDs, both the mortality and morbidity from device-related infections are significantly higher in transvenous ICD systems.[12]

A general challenge for the implantation of the S-ICD is adequate sensing through the device to avoid QRS or T-wave oversensing, which might lead to inappropriate shocks, and several predictors of failed sensing screening have been identified.[12,13] In the S-ICD, sensing occurs via 3 bipolar vectors (primary, secondary, and alternate vector), which are created between the proximal and distal lead electrode and the S-ICD can (Figure 1C). The importance of obtaining sensing templates during exercise testing prior to implantation has been illustrated,[14] but this was not feasible in our patient because of his limited mobility owing to foot surgery and his comorbidities. Therefore we had to rely exclusively on resting sensing screening. An alternative option for sensing screening would have been mapping of the optimal electrocardiogram vectors by the time his epicardial pacemaker system was implanted. This could improve the likelihood of sensing success in patients with similar conditions.

In addition to QRS or T-wave oversensing, a concomitant dual-chamber pacemaker exhibits the potential for oversensing of atrial pacing through the S-ICD, as shown in our case (Figure 2A). This problem might be even more common in epicardial pacemaker systems because of the close

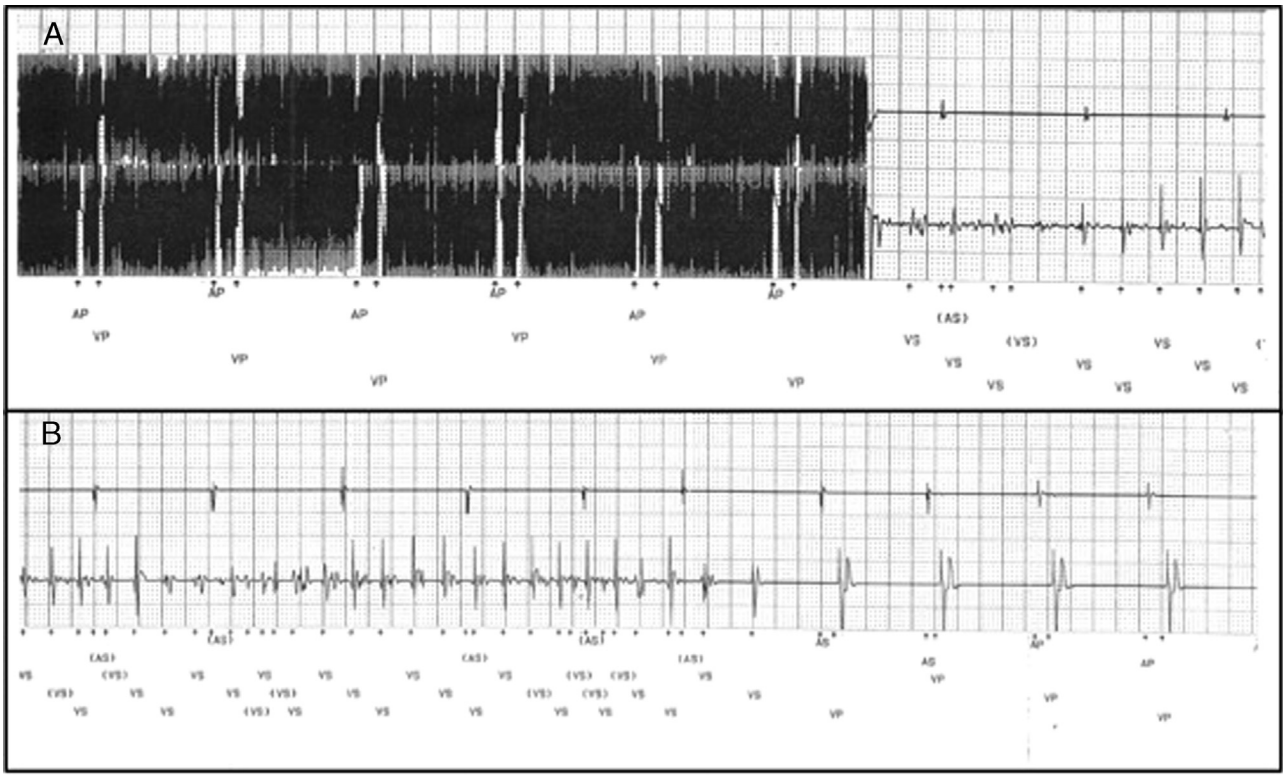

Figure 3 Defibrillation threshold testing. **A:** Ventricular fibrillation (VF) was induced with a 50 Hz train through the subcutaneous implantable cardioverter-defibrillator (S-ICD). The VF induction was not detected by the epicardial dual-chamber pacemaker and continued pacing is recorded during the VF induction. **B:** Subsequently appropriate VF detection by the epicardial pacemaker. Despite several attempts, the inducible VF was self-terminating before shock delivery through the S-ICD. RA = right atrial.

proximity to the subcutaneous ICD lead. For surgical-anatomic reasons epicardial leads are usually placed on the right atrial free wall and alternative atrial lead positions are limited. The fact that we had to implant the S-ICD lead in a right parasternal position put the epicardial atrial leads in proximity to the B electrode and certainly favored atrial oversensing through the S-ICD. Adjustment of the atrial pacing output eliminated double counting by the S-ICD in our case, but will require frequent and careful reassessment during follow-up. The risk of atrial oversensing might be lower in an S-ICD system with a standard left parasternal lead position. Another generally important issue is the inactivation of the lead polarity switch in the pacemaker system to avoid unipolar pacing, which might increase the chances of double counting on the S-ICD.[11]

Strategies to avoid double counting of atrial and ventricular pacing through the S-ICD include minimizing of the atrial pacing output to the lowest acceptable values and programming the trigger rate for VF detection to $>2\times$ the upper pacing rate. In our case, we programmed the upper pacing rate to 100 bpm and the detection rate for VF to ≥ 220 bpm. An upper pacemaker rate of 100 bpm was thought to be acceptable for our elderly patient with a very limited mobility at baseline, but such a programming might not be appropriate for younger and more active patients. Thus, even in the case of double counting of atrial and ventricular pacing the sensed rate through the S-ICD would still be below the VF detection threshold and should not cause inappropriate shocks.

In our case, inducible VF was correctly detected by the epicardial pacemaker (Figure 3B), but the VF induction was missed (Figure 3A). Continued pacing during VF might cause VF undersensing by the S-ICD and withhold appropriate therapy. The rationale for this concern is the voltage difference between paced beats and low-voltage VF (0.1-0.3 mV in our case). The role of follow-up DFT testing is as yet undetermined.

The major limitation of our report is a limited follow-up period, which does not allow us to draw any conclusions concerning the long-term efficacy and safety of the combination of S-ICD and permanent epicardial pacemaker in patients with secondary prevention ICD.

Another limitation of our report is the absence of documented defibrillation efficacy for inducible VF at the time of implantation. The inability to induce sustained VF was the reason to abandon intraoperative DFT testing after multiple unsuccessful attempts and a prolonged procedure. Nevertheless, an elective DFT testing should be considered during his follow-up in this patient with a secondary prevention ICD and a history of appropriate ICD shocks in the past.

At present, the combination of S-ICD with a concomitant permanent pacemaker should be limited to highly selected patients and the implantation should only be performed in specialized centers. The complex interaction between S-ICD and permanent pacemaker requires close follow-up by a center experienced in complex device conditions in order to address the challenging issues of device programming.

Conclusion

Complex extravascular pacing and an ICD system may be required in selected patients. We report the feasibility and safety of co-implantation of an S-ICD and a permanent epicardial pacemaker. Device programming is challenging because of the complex interaction of 2 separate devices, but this approach does seem feasible.

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