Surgical and electrophysiological considerations in the management of a patient with a subcutaneous implantable cardioverter-defibrillator undergoing coronary artery bypass surgery

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Introduction

The use of the implantable cardioverter-defibrillator (ICD) has been the standard of care in the management of patients who have experienced sudden cardiac death and also for those patients at risk for life-threatening ventricular arrhythmias.[1] These transvenous systems carry a substantial risk of periprocedural complications including pneumothorax, cardiac perforation, pericardial effusion or tamponade, hemothorax, venous thrombosis, lead failure or fracture, and infection.[2,3] In 2010, Bardy et al reported the first successful use of a completely subcutaneous ICD (S-ICD) that is expected to obviate these risks.[4] The U.S. Food and Drug Administration has approved the S-ICD for use in indicated patients without the need for ventricular pacing or cardiac resynchronization therapy.[5] The S-ICD has been effective in the management of at-risk patients; however, its use in surgical patients has been limited. Temporary pacing and sternal wires have interfered with normal S-ICD device function; hence, careful placement of the subcutaneous lead in candidates for cardiac surgery requiring a median sternotomy is of utmost importance.[6,7] We present the first reported case of a patient with an existing S-ICD system who underwent a median sternotomy for coronary artery bypass graft (CABG) surgery in which removal and repositioning of the S-ICD lead was performed.

KEYWORDS Ventricular tachycardia; Coronary artery bypass surgery; Implantable cardioverter-defibrillator; Sudden cardiac arrest; Cardiomyopathy
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Case report

In February 2016, a 34-year-old man with a history of idiopathic dilated cardiomyopathy for many years and a left ventricular ejection fraction of 20% was referred to the electrophysiology service for ICD implantation. He had a history of nonsustained ventricular tachycardia and unexplained syncope. His electrocardiogram revealed normal sinus rhythm without conduction abnormalities and a narrow QRS duration. He was considered to have NYHA functional class II heart failure symptoms on optimum medical therapy. He underwent successful S-ICD placement and his postprocedure course was uneventful. A chest radiograph revealed normal S-ICD lead and generator positions and the electrogram recording from the S-ICD lead demonstrated normal sensing function (Figure 1). Ventricular fibrillation was induced at implantation utilizing 50 Hz stimulation from the device and defibrillation was successful with a 65 J shock. No evidence of oversensing or undersensing was evident.

Approximately 2 months following S-ICD implantation, he presented to the emergency room at our institution with acute substernal chest discomfort and shortness of breath with new reversible anterior wall ischemia on pharmacologic stress testing, despite the absence of a previous history of chest pain, and despite prior negative stress test for myocardial ischemia a few years earlier. Coronary angiography revealed evidence of severe triple vessel coronary artery disease and bypass surgery was recommended. The patient underwent planned coronary artery bypass grafting with specific provision for handling of the S-ICD lead that was lying in the field of a standard median sternotomy incision. S-ICD lead positioning was undertaken to assure that the distal or proximal sensing electrode was not in contact with any sternal wires (Figure 2).

There is to date no clear guideline for managing a patient with an existing S-ICD lead during median sternotomy, and

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KEY TEACHING POINTS

- The subcutaneous implantable cardioverter-defibrillator (S-ICD) is useful in the prevention and treatment of patients with life-threatening ventricular arrhythmias and the lead system may be repositioned safely in patients undergoing coronary artery bypass graft surgery.
- Repositioning of the S-ICD lead in association with the performance of a median sternotomy must be carefully undertaken to avoid contact with sternal wires.
- S-ICD lead testing to discriminate QRS and T-wave amplitude ratio must be undertaken to insure appropriate sensing to enable effective detection and treatment of ventricular tachyarrhythmias.

so we aim to demonstrate our effective treatment of this clinical scenario. In anticipation that thoracic surgery in patients with an existing S-ICD is likely to become more frequent, given the increasing number of implanted S-ICDs, we believe that it is essential to address an approach to prevent potential complications related to sternal wires, as well as other technical and electrophysiological considerations.

Surgical technique

In the cardiothoracic surgery operating room, the patient was prepped and draped in the standard way for CABG surgery. Following a small paraxiphoid incision over the preexisting incision, the anchoring sleeve of the sternal lead was located, the suture sleeve was exposed but not freed from its anchoring sutures, and the lead was pulled back through this small incision to be kept outside of the body between antibiotic-infused packing mesh. The lead was kept protected in this manner while a standard sternotomy proceeded and bypass surgery was performed without complication. Following successful bypass grafting and standard closure of the sternum with sternal wires, the subcutaneous defibrillator lead was reirrigated with antibiotic-infused saline and replaced on top of the fascial plain overlying the sternum, consistent with the original lead position. The lead was nested into a central position (Figure 3) above which the subcutaneous and skin layers were closed in the standard fashion. Care was taken to avoid any contact between the electrode and sternal wires to avoid oversensing.[6]

Postsurgical management and device testing

Pre– and post–vector analysis of the QRS and T-wave amplitudes was measured from the S-ICD lead and the results met acceptable criteria along all measured vectors for effective QRS and T-wave discrimination (Figures 1 and 2). During postoperative in-hospital follow-up this effective QRS and T-wave complex discrimination remained consistent with the preoperative measurements. The patient had an uneventful postoperative course and was discharged from the hospital after 7 days, in good condition. He returned to the electrophysiology clinic after 1 week for an incision check, and routinely 2 months later. All the incision sites were well healed and the S-ICD was functioning normally, with adequate QRS and T-wave discrimination.

Discussion

To our knowledge, this is the first detailed description of the perioperative management of a patient with an existing S-ICD lead who underwent CABG surgery via median sternotomy in which explantation and reimplantation of the same lead was performed. Additional considerations to address involve the assessment of QRS voltage in the immediate postoperative period, as it has been reported that the QRS amplitude is often diminished following open chest surgical procedures and this may interfere with QRS and T-wave discrimination, an essential parameter that allows accurate arrhythmia detection and minimizes the risk of oversensing the T wave and inappropriate shocks.[6–8]

To avoid spurious recordings, artifacts, and oversensing, caution should be taken to avoid placing the rate sensing electrodes of the S-ICD lead in close proximity to sternal wires, as this may impact sensing, particularly in the secondary and alternate sensing vector of the device. Infusino et al cited oversensing of epicardial pacing spikes by the S-ICD resulting in inappropriate shocks in a patient undergoing aortic and mitral valve replacement.[7] Their experience should serve as a caveat to clinicians when managing patients who are at risk for bradyarrhythmias in the perioperative period.

The S-ICD has been effective and safe in patients at risk for sudden cardiac death who do not require antitachycardia pacing, bradycardia support, or cardiac resynchronization therapy.[4,9–11] Traditional transvenous ICDs are associated with an approximately 5% complication rate within 30 days of implantation, a 16%–20% chance of lead failure over 10 years, and a 2.4% annual incidence of infection.[2,3,12–14] Systemic infections and endocarditis remain a concern in the use of these traditional devices. In addition, the risk of infection has risen along with the increasing numbers of invasive procedures, including generator replacement.[14] Device-associated infections may have high morbidity and mortality rates and can be fatal when associated with bacteremia and evidence of endocarditis. Accordingly, the extravascular nature of the S-ICD lead is expected to reduce the potential for life-threatening infectious sequelae in these patients.

S-ICDs can sense the QRS complex in 3 vectors, using 2 elements on the electrode—the distal tip and proximal ring—as well as the pulse generator.[10] It has been demonstrated in this case that there was no significant change in the sensed QRS vector amplitude and QRS/T-wave amplitude ratio after the median sternotomy and reimplantation of the S-ICD

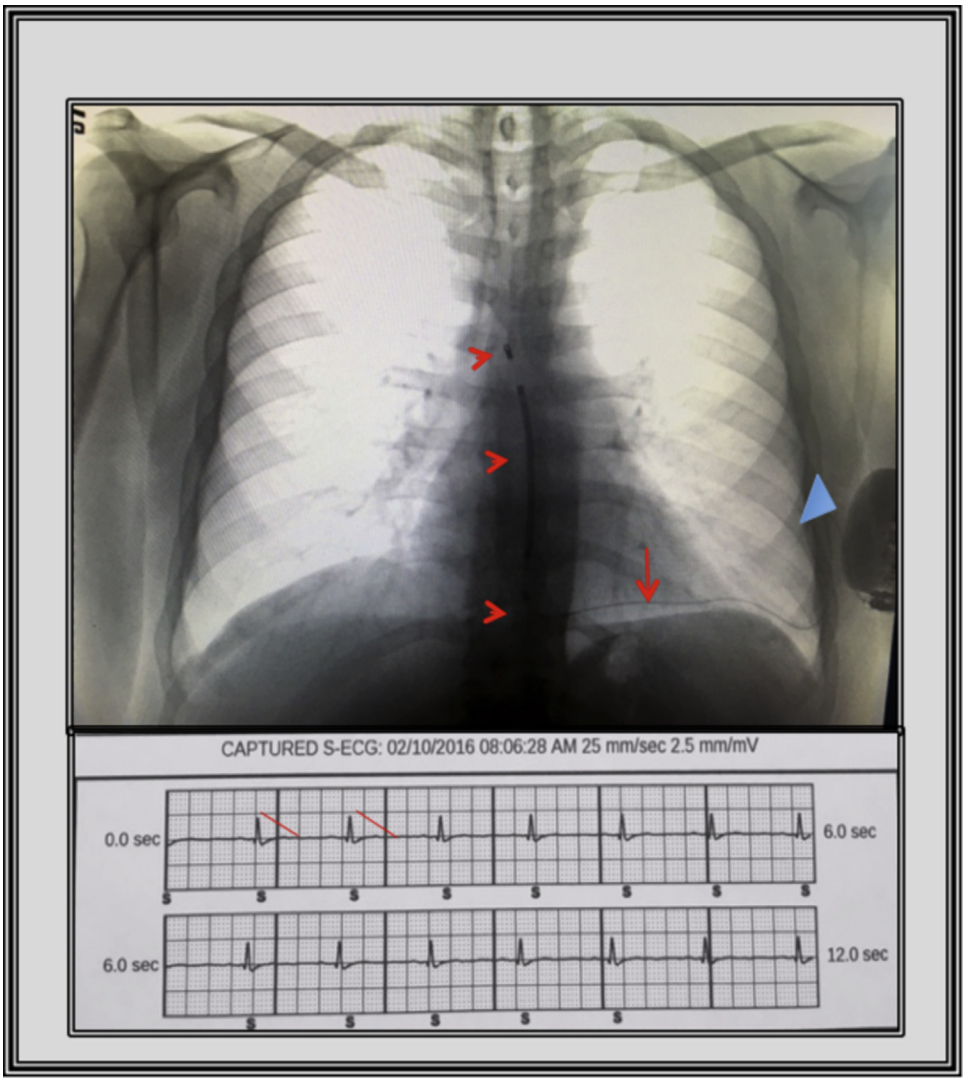

Figure 1 The upper image shows the pre–coronary artery bypass graft (CABG) chest radiograph demonstrating the position of the subcutaneous implantable cardioverter-defibrillator sternal lead and generator. The *upper red arrowhead* points to the distal tip of the subcutaneously tunneled sensing electrode of the sternal lead, the *middle red arrowhead* points to the shock coil of the lead, and the *lower red arrowhead* points to the subxiphoid proximal sensing electrode and anchoring sleeve position of the lead. The *long red arrow* points to the transthoracic portion of the subcutaneously tunneled lead and the *blue triangle* points to the implanted position of the generator of the subcutaneous defibrillator. The lower pictured electrocardiogram shows a pre-CABG tracing from the lead II vector configuration of the subcutaneous recording from the distal electrodes to the can, demonstrating adequate QRS/T-wave ratio of 5:1, demonstrated by the superimposed orange discrimination template.

lead. For this device to be successfully implanted it must meet criteria for effective QRS/T-wave discrimination.

In this demonstrated case of lead removal and replacement, the pre- and poststernotomy QRS/T-wave amplitude ratio was adequate in all measured vectors. Even in the immediate postoperative period when there was the highest expectation for postsurgical thoracic impedance changes related to pericardial and pleural effusions and inflammation that could cause altered QRS/T-wave sensing and signal differentiation, the values remained stable and optimal for sensing. The presence of suboptimal QRS/T-wave amplitude discrimination owing to either a small QRS complex or the postoperative state itself may result in oversensing or undersensing. Consequently, spurious shocks or failure to recognize tachyarrhythmias in need of therapy may occur. We suggest that QRS amplitude surveillance should be performed intraoperatively via the S-ICD programmer and sternotomy closure initiated as described once the S-ICD lead is secured and adequate sensing confirmed. This will eliminate the need to program tachycardia detection off during the immediate in-hospital postoperative period. If sensing function is found to be suboptimal in the postoperative period, S-ICD tachycardia detection may be programmed off, the patient monitored in a setting where an external defibrillator is available, and repeat evaluation performed before discharge. Persistence of sensing abnormalities may be managed by prescribing the use of a wearable cardioverter-defibrillator and device testing may be repeated once postoperative healing is complete in 6 weeks or so.[15]

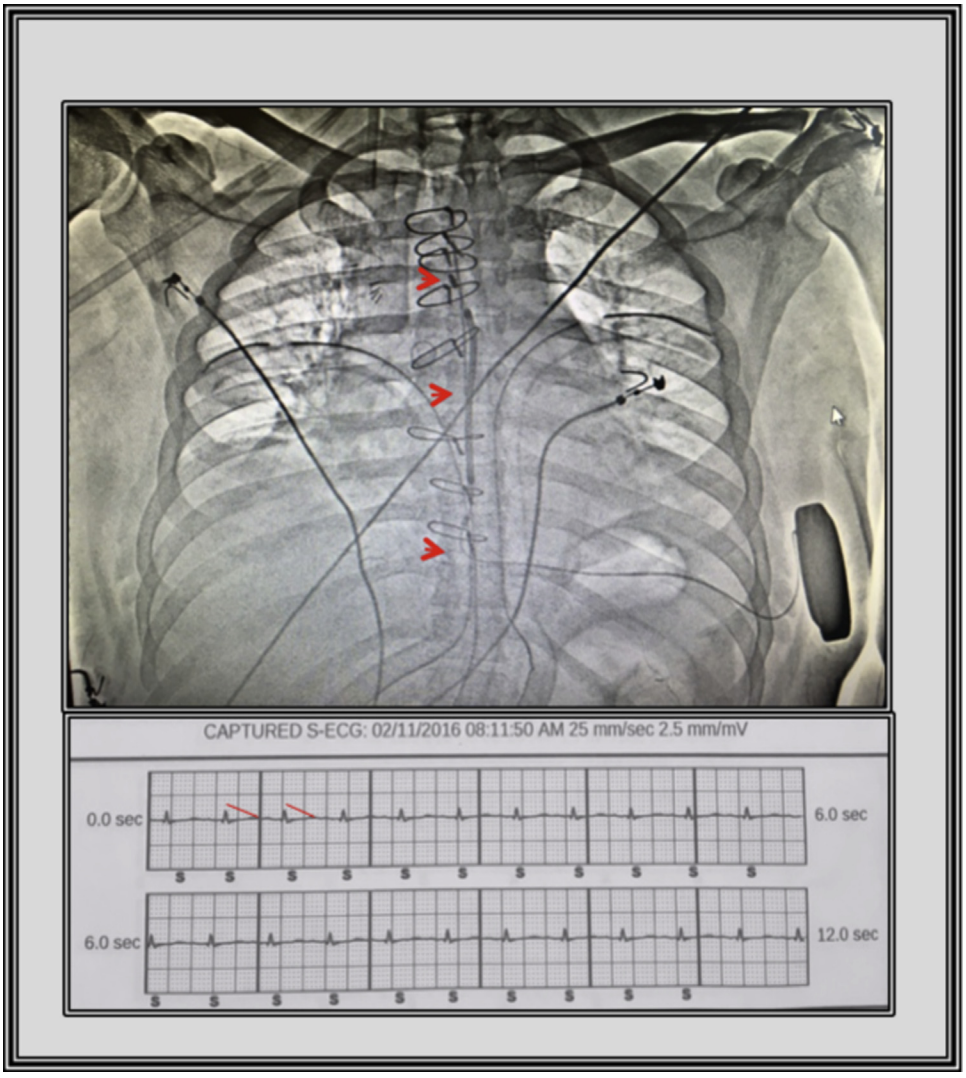

Figure 2 The upper image shows the post–coronary artery bypass graft (CABG) chest radiograph demonstrating the position of the subcutaneous implantable cardioverter-defibrillator lead and generator. The *upper red arrowhead* points to the distal tip of the subcutaneously tunneled sensing electrode of the sternal lead carefully placed to avoid any possible contact with the sternal wires that could contribute to noise sensing, the *middle red arrowhead* points to the shock coil of the lead, and the *lower red arrowhead* points to the subxiphoid proximal sensing electrode and anchoring sleeve of the lead, which was exposed but not released during the surgery, therefore retaining the exact same position post-CABG. The transthoracic portion of the subcutaneously tunneled lead and implanted position of the generator of the subcutaneous defibrillator remain unaltered by the surgery. The lower pictured electrocardiogram shows a post-CABG tracing from the lead II vector configuration of the subcutaneous recording from the distal electrodes to the can, demonstrating a slightly diminished but still adequate QRS/T-wave ratio of 3:1, demonstrated by the superimposed orange discrimination template. At repeated outpatient testing post-discharge the QRS/T-wave ratio was back to the 5:1 baseline.

This case report demonstrates that an S-ICD lead can be safely removed and then successfully replaced provided that careful precautions are undertaken regarding the sternal lead field. The surgical technique implemented was successful in this case and serves as a basis for defining a methodological approach to facilitate successful management of patients with an S-ICD requiring a median sternotomy or thoracic surgery that involves the sternal lead location.

S-ICDs are being implanted far more frequently now and this trend will continue, especially with the future potential for leadless right ventricular pacing developments. It is therefore likely that there will need to be established guidelines and recommendations for effective handling of the device and lead during and after thoracic surgery, to allow for continued reliable arrhythmia identification and successful defibrillation therapy, when appropriate.

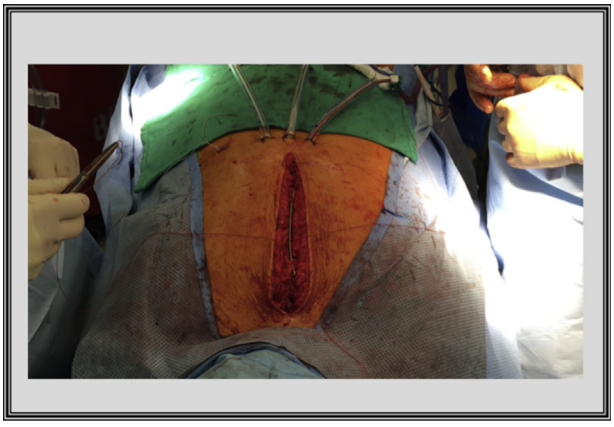

Figure 3 Intraoperative photograph demonstrating the post–coronary artery bypass graft replacement of the sternal lead, after sternal wiring and thoracic cavity closure had been completed, but before subcutaneous and skin layers had been closed.

References

1. Epstein AE, DiMarco JP, Ellenbogen KA, et al. ACC/AHA/HRS 2008 Guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to revise the ACC/AHA/ NAPSE 2002 Guideline update for implantation of cardiac pacemakers and antiarrhythmia devices): developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons [published erratum appears in Circulation 2009;120:e34–35]. Circulation 2008;117:e350–e408.
2. Borleffs CJ, van Erven L, van Bommel RJ, van der Velde ET, van der Wall EE, Bax JJ, Rosendaal FR, Schalij MJ. Risk of failure of transvenous implantable cardioverter-defibrillator leads. Circ Arrhythm Electrophysiol 2009;2:411–416.
3. Krahn AD, Lee DS, Birnie D, et al. Predictors of short-term complications after implantable cardioverter-defibrillator replacement: results from the Ontario ICD Database. Circ Arrhythm Electrophysiol 2011;4:136–142.
4. Bardy GH, Smith WM, Hood MA, et al. An entirely subcutaneous implantable cardioverter-defibrillator. N Engl J Med 2010;363:36–44.
5. FDA Approval of Subcutaneous Defibrillator System. Available at: ⟨http://www.accessdata.fda.gov/cdrh_docs/pdf11/P110042a.pdf⟩. Accessed August 29, 2016.
6. Winter J, Kohlmeier A, Shin DI, O'Connor S. Subcutaneous implantable cardioverter-defibrillators and sternal wires: a cautionary tale. Circ Arrhythm Electrophysiol 2014;7:986–987.
7. Infusino T, Valsecchi S, Rigano M, Maselli D. Perioperative management of a patient with subcutaneous defibrillator undergoing cardiac surgery. Springerplus 2015;4:533.
8. Crescenzi G, Scandroglio AM, Pappalardo F, Landoni G, Cedrati V, Bignami E, Aletti G, Zangrillo A. ECG changes after CABG: the role of the surgical technique. J Cardiothorac Vasc Anesth 2004;18:38–42.
9. Kobe J, Reinke F, Meyer C, Shin DI, Martens E, Kaab S, Loher A, Amler S, Lichtenberg A, Winter J, Eckardt L. Implantation and follow-up of totally subcutaneous versus conventional implantable cardioverter-defibrillators: a multicenter case-control study. Heart Rhythm 2013;10:29–36.
10. Cappato R, Smith WM, Hood MA, Crozier IG, Jordaens L, Spitzer SG, Ardashev AV, Boersma L, Lupo P, Grace AA, Bardy GH. Subcutaneous chronic implantable defibrillation systems in humans. J Interv Card Electrophysiol 2012;34:325–332.
11. Dabiri Abkenari L, Theuns DA, Valk SD, van Belle Y, de Groot NM, Haitsma D, Muskens-Heemskerk A, Szili-Torok T, Jordaens L. Clinical experience with a novel subcutaneous implantable defibrillator system in a single center. Clin Res Cardiol 2011;100:737–744.
12. Ellenbogen KA, Hellkamp AS, Wilkoff BL, Camunas JL, Love JC, Hadjis TA, Lee KL, Lamas GA. Complications arising after implantation of DDD pacemakers: the MOST experience. Am J Cardiol 2003;92:740–741.
13. Grimm W, Flores BF, Marchlinski FE. Complications of implantable cardioverter defibrillator therapy: follow-up of 241 patients. Pacing Clin Electrophysiol 1993;16:218–222.
14. Greenspon AJ, Patel JD, Lau E, Ochoa JA, Frisch DR, Ho RT, Pavri BB, Kurtz SM. 16-year trends in the infection burden for pacemakers and implantable cardioverter-defibrillators in the United States 1993 to 2008. J Am Coll Cardiol 2011;58:1001–1006.
15. Chung MK, Szymkiewicz SJ, Shao M, Zishiri E, Niebauer MJ, Lindsay BD, Tchou PJ. Aggregate national experience with the wearable cardioverter-defibrillator: event rates, compliance and survival. J Am Coll Cardiol 2010;56:194–203.