Shock vector modulation via axillary vein coil in a right-sided implantable cardioverter-defibrillator

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Introduction

In the early years of implantable cardioverter-defibrillator (ICD) placement, defibrillation threshold (DFT) testing was often routinely performed at the time of the initial implantation.[1] Subsequent randomized clinical trials comparing routine DFT testing to omission of DFT testing at implantation showed no clinical difference in the efficacy of subsequent appropriate ICD shocks, arrhythmic death, and all-cause mortality.[2,3] Given this evidence, routine DFT testing is no longer recommended and is rarely performed clinically except in special circumstances.[1]

The randomized controlled trials of DFT testing (the Shockless Implant Evaluation [SIMPLE] trial and the No Regular Defibrillation Testing in Cardioverter Defibrillator Implantation [NORDIC ICD] trial)[2,3] notably excluded patients with right-sided ICD implants, patients with cardiomyopathy who were actively listed for a heart transplant, patients with hypertrophic cardiomyopathy and arrhythmogenic right ventricular (RV) cardiomyopathy, and patients with other significant comorbidities; these patients may benefit the most from selective DFT testing. Several smaller studies have shown higher DFTs and reduced acute defibrillation success at the time of implantation in right-sided devices compared with left-sided devices.[1] This is likely owing to the suboptimal electrical vector for defibrillation from an RV coil electrode to a right-sided generator, which fails to encompass the majority of the left ventricular mass, compared with conventional left-chest ICD implants. In the absence of robust evidence to guide clinical decision-making, many clinicians perform DFT testing at the time of right-sided ICD implantation in select patients at higher risk of failed defibrillation.[1]

We present a case in which a right-sided ICD with a single-coil lead was placed, DFT testing at implantation failed, and a second transvenous coil was added in a novel location to optimize the shock vector, resulting in subsequent successful defibrillation.

KEY TEACHING POINTS

- Routine defibrillation threshold testing is not recommended at the time of de novo defibrillator implantation; however, randomized controlled trials of defibrillation threshold testing excluded patients with right-sided implantable cardioverter-defibrillators (ICDs) and comorbidities who may benefit the most from selective defibrillation threshold testing.
- Right-sided ICDs may have higher defibrillation thresholds and reduced acute defibrillation success owing to the suboptimal electrical vector for defibrillation from a right ventricular coil to a right-sided generator.
- There are multiple options for shock vector modulation via addition of transvenous, subcutaneous, or epicardial coils or arrays, although the placement of a second defibrillation coil in the left axillary vein is not commonly suggested.
- The left axillary vein is a simple, procedurally expedient, and effective location for additional DF-1 defibrillation coil placement to optimize the electrical vector for defibrillation in a patient with a right-sided ICD with otherwise unacceptably high defibrillation thresholds.

Case report

The 66-year-old female patient had a history of ischemic cardiomyopathy with a left ventricular ejection fraction of 16% despite maximally tolerated heart failure therapy; thus, a single-chamber ICD for primary prevention was recommended. She also had severe aortic stenosis (with concomitant

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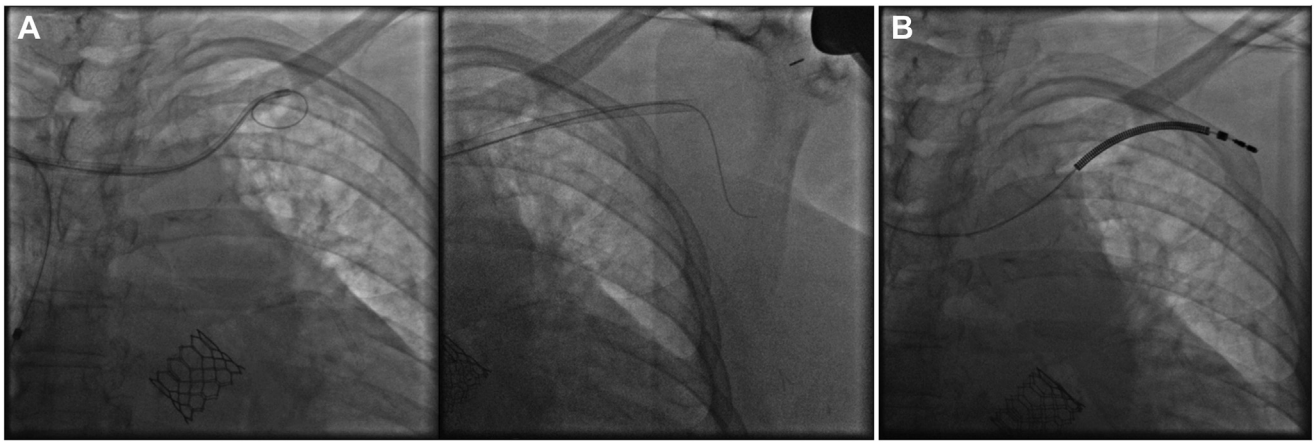

Figure 1 Fluoroscopy images of axillary lead placement for a right-sided single-chamber implantable cardioverter-defibrillator, with a second DF-1 defibrillation coil placed in the left axillary vein. **A:** Access to the left axillary vein from a right subclavian venous approach. **B:** Final axillary lead placement.

left ventricular hypertrophy) treated with a transcatheter aortic valve replacement. Other comorbidities included a history of severe tricuspid valve regurgitation, obesity (body mass index 37.64 kg/m^2), and diabetes mellitus type II. The ICD implantation was further complicated by a history of ductal carcinoma in situ of the left breast with lymphovascular invasion that had been treated with a partial mastectomy of the left breast followed by radiation and chemotherapy. The care team decided to proceed with a right-sided ICD generator placement because of this. Electrolytes were normal, and the patient was not taking any antiarrhythmic medications prior to the procedure.

A single-chamber ICD was placed via right subclavian venous approach under monitored anesthesia care. A Biotronik DX single-coil ICD lead (Plexa ProMRI DF-1 DX; Biotronik SE & Co, Berlin, Germany) and right-sided generator were placed uneventfully. The right atrial P wave was sensed at 4.3 mV. The RV R wave was sensed at 12 mV, with a pacing impedance of 562 ohms and a pacing threshold of 0.5 V at 0.4 ms. The defibrillation circuit used the coil as the cathode (the default setting) with an impedance of 68 ohms. DFT testing was deemed appropriate because of the right pectoral ICD generator and many other clinical factors that increased her risk for high DFTs and failed defibrillation. Ventricular fibrillation was induced with a T-wave-synchronous low-energy shock, and it was appropriately detected by the device. A 30 J / 62 ohm shock delivered from the generator casing (anode) to the RV (cathode) failed to convert the ventricular fibrillation. External defibrillation with a 360 J rescue shock restored sinus rhythm.

A second single-coil DF-1 lead was placed in the left axillary vein to optimize the shock vector. After the right subclavian vein was accessed, a 0.035-inch Glidewire (Terumo Interventional Systems, Franklin Township, NJ) was advanced into the left axillary vein using a 5 French vein selector (Merit Medical Systems, South Jordan, UT) to cross a prominent valve at the subclavian-axillary junction (Figure 1A). A long 9F sheath was advanced into the left axillary vein over the guidewire. Through this sheath, a Biotronik DF-1 lead was advanced into the left axillary vein. The lead was actively fixed in the left axillary vein by extending the screw into the vein wall. The DF-1 pin of the axillary lead was connected to the superior vena cava (SVC) port of the ICD generator. The pace-sense lead pin was capped. Measured shock impedance was 60 ohms from the axillary vein to the RV coil (programmed defibrillation polarity SVC-to-RV). Of note, the use of a unipolar ICD coil (eg, Transvene 6937A; Medtronic, Minneapolis, MN) would eliminate the bulky yoke and the need to cap the pace-sense IS-1 pin, but this lead was not available at our institution.

DFT testing was repeated. Ventricular fibrillation was induced as before, and a 30 J / 63 ohm shock was delivered from the axillary vein (anode) to the RV coil (cathode). This shock again failed, and external defibrillation was performed to restore sinus rhythm. Further DFT testing was not pursued, as it was suspected that multiple shocks, the dose of propofol used during the procedure, and the polarity of the shocks could be factors contributing to unsuccessful defibrillation. We concluded the procedure and closed the surgical incision; a repeat DFT test was planned for the following day. Cardiovascular surgery was on standby for surgical subxiphoid epicardial defibrillation patch placement in the event that repeat DFT testing failed. Figure 1B shows a fluoroscopy image of the final axillary lead placement. Figure 2 shows a chest radiography image from postoperative day 0.

On postoperative day 1, DFT testing was repeated under anesthesia. Ventricular fibrillation was induced, and it was appropriately detected by the ICD. A 40 J / 59 ohm shock with a biphasic 2 waveform and reversed polarity from the RV coil (anode) to the axillary vein coil (cathode) (programmed RV-to-SVC) successfully restored normal sinus rhythm.

Final device interrogation showed RV sensing at 16.1 mV, pacing impedance of 562 ohms, coil impedance of 68 ohms, and pacing threshold of 0.4 V at 0.4 ms. Axillary coil impedance was 63 ohms. She was subsequently

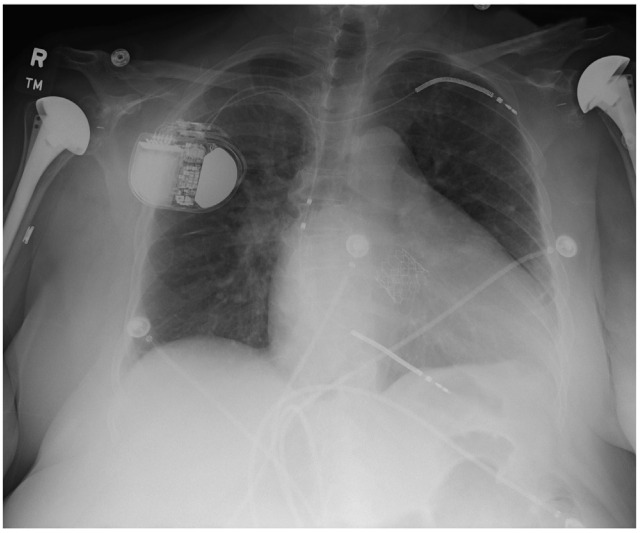

Figure 2 Chest radiograph from postimplant day 0.

discharged home the same day. At follow-up 2 weeks later, shock impedance remained stable at 68 ohms.

Discussion

This is the first reported case of an adult patient with a right-sided ICD in whom a second defibrillation coil was placed in the left axillary vein to optimize the shock vector. This patient had multiple factors contributing to reduced defibrillation efficacy. The electrical vector for defibrillation, from an RV coil to a right infraclavicular generator, was suboptimal, as it excluded most of the dilated and hypertrophied left ventricle. Additional factors included obesity and prolonged sedation with propofol, which have been shown to increase DFTs.[1,4]

Commonly used initial strategies for patients in whom DFT testing has failed include changing the defibrillation polarity and modifying the biphasic shock waveform by adjusting tilt or by truncation of the second phase in certain devices.[4,5] Although some devices provide the option of programming a fixed-tilt vs tuned (optimized) biphasic defibrillation waveform, for right-sided ICDs this may not affect the DFT.[6] The RV coil can be repositioned in a more apical and septal location to improve the shock vector.[4] More complex strategies include adding a second transvenous defibrillation coil in the SVC, azygos/hemiazygos vein, or coronary sinus, or adding subcutaneous coils or arrays to lower the DFT.[4,7] Surgically implanted epicardial patches or coils have been used in the most difficult cases.[4,7] The use of a second defibrillation electrode in the left subclavian vein, compared with a second electrode in the superior vena cava, has been previously studied in left-sided implantations of early ICDs prior to the development of "active can" devices, using both monophasic[8] and biphasic[9] shock waveforms. The placement of a second defibrillation coil in the left brachiocephalic (innominate), left subclavian, or left axillary vein is less commonly suggested in contemporary devices,[4,7] although this is a relatively simple and effective way to alter the shock vector in right-sided implants. This strategy has only been reported 3 times before in patients with right-sided ICDs and high DFTs: in 1 case a second coil was placed in the left axillary vein in a pediatric patient,[10] and in the other 2 a second coil was positioned in the left brachiocephalic vein and left subclavian vein, respectively.[11,12]

In our patient, the RV defibrillation coil was already optimally placed with the lead tip in the RV apex. We decided against placing a tunneled right or left subcutaneous array, as this might not have significantly changed the defibrillation vector and would have required general anesthesia in a patient with significant comorbidities. A second coil in the SVC also would not have significantly changed the shock vector. We rejected the option of placing a defibrillator lead in the coronary sinus because of the risks of potential lead instability, chronic stenosis of the coronary sinus, and interference with placement of a future pace-sense lead for cardiac resynchronization therapy if indicated. We were unable to access the azygos vein with a wire from the right subclavian venous approach, and a contrast allergy precluded venograms to facilitate azygos vein cannulation. Thus, we decided to place a second defibrillation coil in the left axillary vein.

This case report demonstrates an uncommonly used but procedurally expedient and effective location for additional DF-1 defibrillation coil placement in the axillary vein to optimize the electrical vector for defibrillation in a patient requiring a right-sided ICD implant with otherwise unacceptably high DFTs. This coil location is technically simpler than azygos vein access from a right subclavian venous approach; it avoids impeding coronary sinus access if cardiac resynchronization therapy is needed; and it does not require general anesthesia, painful tunneling procedures, or surgical epicardial access.

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