INNOVATIVE COLLECTIONS

COMPLEX CASE STUDY

Combination of Azygous Vein Coil and Subcutaneous Array Required for Adequate Defibrillation Efficacy

GANESH VENKATARAMAN, MD and S. ADAM STRICKBERGER, MD

Washington Electrophysiology and Cardiovascular Research Institute, Washington Hospital Center, Washington, DC

ABSTRACT. Inadequate defibrillation efficacy (DE) requiring device modification is a small, but significant problem in patients undergoing placement of an implantable cardioverter-defibrillator (ICD). Management options for a patient with inadequate DE includes repositioning of the right ventricular (RV) ICD lead, reversal of the shock polarity, removal of the superior vena cava (SVC) coil from the shock vector, and modification of the biphasic waveform tilt and/or pulse width. If these or other maneuvers fail to achieve adequate DE, a subcutaneous defibrillation (SQ) array is often placed. An alternative strategy, the placement of a defibrillation coil in the azygous vein, has also been shown to improve DE. We describe a patient who required an azygous vein defibrillation coil (AVC) and a SQ array to achieve adequate DE.

KEYWORDS. azygous vein coil, defibrillation efficacy, defibrillation threshold, implantable defibrillator, subcutaneous array.

Case report

A 55-year-old man with a past history of severe alcohol use, a non-ischemic cardiomyopathy with New York Heart Association functional class II heart failure, and left ventricular ejection fraction of 0.25 was referred for elective placement of an ICD for primary prevention of sudden cardiac death. His medical regimen was optimal and included a β-blocker and an angiotensin converter enzyme inhibitor. Plasma electrolytes, including potassium, ionized calcium, and serum creatinine, were within normal limits. The electrocardiogram showed sinus rhythm with normal PR and QT intervals, left ventricular hypertrophy, and a QRS duration of 118 ms.

A dual-chamber ICD (St. Jude Medical, St. Paul, MN; Model CD 2211-36Q) was implanted in the left chest, and a dual-coil ICD lead with an DF-4 connector (St. Jude Medical; Model 7120Q) was placed in the RV apex. Capture threshold, sensing, and impedance were 0.5 V at 0.4 ms, 25 mV, and 512 Ω, respectively. A pacemaker lead (St. Jude Medical; Model 1888TC) was placed in the right atrial (RA) appendage with capture threshold, sensing, and impedance of 0.9 V at 0.4 ms, 3.3 mV, and 488 Ω, respectively. Sedation was achieved with midazolam and fentanyl. Ventricular fibrillation (VF) was induced. Using a biphasic waveform with 65% fixed tilt, a shock of 15 J failed, as did a second shock of 25 J with the same waveform morphology. The shock impedance was 36 Ω. A 200-J external shock was delivered and was successful in restoring sinus rhythm. The biphasic waveform was optimized, based on the shock impedance, to a fixed pulse width of 3.5 ms/3.5 ms. VF was induced a second time. A 25-J shock, followed by a 35-J shock with the same waveform morphology, failed. A 200-J external shock was successful. The pocket was closed and the procedure completed. The patient left the electrophysiology laboratory in stable condition.

The patient returned to the electrophysiology laboratory the following day for implantation of an AVC. Anesthesia was achieved with midazolam, fentanyl, and propofol. The DF-4 header of the ICD generator is not compatible with an additional defibrillation electrode.

Drs. Venkataraman and Strickberger are speaker/consultants for St. Jude Medical. Dr. Strickberger is a principal investigator for Cameron Health.


Address correspondence to: Ganesh Venkataraman, MD, 106 Irving Street, NW, Suite 204, South Tower, Washington, DC 20010-2975. E-mail: Ganesh.S.Venkataraman@medstar.net
Consequently, both the ICD generator and the RV ICD lead were removed. A single-coil ICD lead (St. Jude Medical; Model 7122) was placed in the RV apex with capture threshold, sensing, and impedance of 0.75 V at 0.4 ms, 5.5 mV, and 430 Ω, respectively. Using a previously described technique,5,6 a single-coil ICD lead (St. Jude Medical; Model 7122) was placed in the azygous vein (Figure 1). The high-voltage connector of the AVC was attached to the SVC port of the new ICD generator (St. Jude Medical; Model CD 2211-36). The pace-sense connector of the AVC was capped. VF was induced. A 25-J shock with an optimized pulse width of 3.5 ms/3.0 ms, followed by a 35-J shock of the same waveform morphology: both failed. The shock impedance was 36 Ω. A 200-J external shock was delivered and was successful. A SQ array (Boston Scientific, St. Paul, MN; Model 0085) was placed with the three defibrillation coils positioned posterior and lateral to the heart (Figure 2). The AVC was connected to the Y adapter of the SQ array, which was then connected to the SVC port of the ICD generator. VF was induced. A single 30-J shock with an optimized pulse width of 3.5 ms/3.5 ms converted the patient to sinus rhythm. The shock impedance was 31 Ω. The patient left the electrophysiology laboratory in stable condition and was discharged the following day. At 1-month follow-up, the patient had normal ICD function and had not received any ICD shocks.

**Discussion**

Adequate DE is a critical part of the ICD implant procedure, although there is increasing controversy associated with its role. Without addressing this issue directly, DE testing is generally performed, and adequate DE is typically required. A patient with inadequate DE often requires an additional defibrillation electrode, such as a SQ array. A recent strategy to improve DE involves the placement of a defibrillation coil in the azygous vein.5,6 We have described a patient who required both an AVC and a SQ array to achieve adequate DE.

The data regarding predictors of DE at the time of ICD implant are inconsistent. Studies have identified a variety of clinical predictors of DE. Reduced or inadequate DE is associated with increased left ventricular mass and volume, elevated resting heart rate, amiodarone use, QRS duration, and other factors.8–10 Although inadequate DE may be difficult to predict, when encountered it often requires a modification of the defibrillation system in order to achieve acceptable DE.

In a patient with inadequate DE, one or more defibrillation coils are often tunneled in the subcutaneous tissue from the left chest to a position posterior and lateral of the heart. The SQ array has been shown to effectively improve DE.3,4 Proper placement of subcutaneous defibrillation coils can be challenging for the operator and painful for the patient; prompting a search for alternate options. Placement of a defibrillation coil in the coronary sinus has little effect on DE.11 More recently, the placement of a defibrillation coil in the azygous vein has been described as a safe and effective method to improve DE.5,6 By substituting the SVC coil with an AVC, the shock vector is shifted posteriorly and allows for more energy to reach the posterior and lateral left ventricle.

**Limitations**

This case report has several limitations. First, a dual-coil ICD lead was changed to a single-coil ICD lead in order to accommodate the AVC. The use of a SQ array alone with a dual-coil ICD lead may have achieved adequate DE. However, it is unknown whether the AVC or the SQ array has a more beneficial effect on DE. Second, the same energies and waveform morphologies were not utilized with every defibrillation system, e.g., a first

---

**Figure 1:** Implantation of the azygous vein defibrillation coil (AVC). In the anterior–posterior (AP) view (left), the azygous vein is accessed using a Judkins right catheter and a 0.035-inch straight-tip wire (W). In the AP (middle) and left anterior oblique views (right), a single-coil implantable cardioverter-defibrillator (ICD) lead is placed in the azygous vein. A pacemaker lead in the right atrial (RA) appendage and a single-coil ICD lead in the right ventricular (RV) apex are also present.
shock at 30 J was only used in the final combined AVC–SQ array configuration. Clinically, there is a limit to the number of VF inductions. This precludes testing all possible defibrillation combinations. Finally, differences in anesthesia may have affected DE.

**Clinical implications**

In this patient, adequate DE could not be achieved with either a dual-coil ICD lead or a single-coil ICD lead combined with an AVC at the time of ICD implant. To our knowledge, this is the first published report of the combined use of an AVC and a SQ array in order to obtain adequate DE. As more complex and challenging patients continue to be referred for ICD implantation, electrophysiologists will continue to struggle with obtaining adequate DE in a small subset of these patients. If one can identify patients at higher risk for an inadequate DE, it may allow one to start the procedure with an ICD header which can accommodate several high voltage electrodes. Currently, ICD headers with a DF-4 connector are unable to accommodate more than one high-voltage electrode. While several strategies to improve DE exist, this case illustrates a novel approach to this dilemma.

**References**

9. Strickberger SA, Brownstein SL, Wilkoff BL, Zinner AJ. Clinical predictors of defibrillation energy requirements in patients treated with a nonthoracotomy defibrillator sys-

**Figure 2:** AP chest x-ray of the final ICD system. The RA pacemaker lead, RV ICD lead, AVC, and subcutaneous defibrillation array (SQ) are shown. Abbreviations as in Figure 1.
