INNOVATIVE COLLECTIONS

COMPLEX CASE STUDY

Azygos Vein Coil: Bailout Strategy for High Defibrillation Thresholds

MOUYYAD RAHABY, MD and IMRAN NIAZI, MD

Aurora Cardiovascular Services, Aurora Sinai/Aurora St. Luke’s Medical Centers, University of Wisconsin School of Medicine and Public Health, Milwaukee, WI

ABSTRACT. We describe an unusual case in which an implantable cardioverter-defibrillator failed to defibrillate the patient during testing at implant; rather, an adequate safety margin was achieved only after introduction of a shocking coil into the azygos vein. The azygos vein is an attractive extracardiac target for placement of a shocking coil, as it provides an ideal shock vector. Tools designed for placing epicardial leads via the coronary sinus branches can be adapted to conveniently place the azygos vein coil.

KEYWORDS. azygos vein, defibrillation, implantable cardioverter-defibrillator, shock vector.

Introduction

Elevated defibrillation thresholds (DFTs) are rarely encountered nowadays; the literature suggests an incidence of about 5%, although some older reports claimed up to 10% incidence with first-time implantations. Nevertheless, thresholds can increase over time due to change in myocardial substrate or use of membrane-active drugs such as amiodarone.

We describe an unusual case in which an implantable cardioverter-defibrillator (ICD) failed to defibrillate the patient during testing at implant; rather, an adequate safety margin was achieved only after introduction of a shocking coil into the azygos vein. The azygos vein courses posteriorly to the left ventricle (Figure 1).

A 44-year-old man presented with non-ischemic cardiomyopathy and severely reduced left ventricular (LV) systolic function (ejection fraction 20%). Owing to New York Heart Association class III heart failure and significant mechanical dyssynchrony on tissue Doppler imaging, the patient underwent upgrade to a cardiac resynchronization therapy device as part of the Echocardiography-Guided Cardiac Resynchronization Therapy (EchoCRT) study. The previously implanted right ventricular (RV) lead (Endotak Reliance, Boston Scientific, Natick, MA) was retained, and a new LV lead (Corox OTW, Biotronik, Lake Oswego, OR) was placed successfully. The leads were connected to an ICD (Lumax 540 HF-T, Biotronik). During defibrillation efficacy testing, a 25-joule shock with cathode–anode polarity (RV coil combination of superior vena cava (SVC) coil, and can) failed to convert ventricular fibrillation induced with a T-wave shock, and rescue external defibrillation was required.

Maneuvers to decrease defibrillation energy requirements

A careful review of the possible reversible causes of an elevated DFT revealed no contributory factors, suggesting that intrinsic cardiac disease progression was the likely cause. Reversing polarity (SVC coil–RV coil and can combination), eliminating the SVC coil or can from the shock vector, and decreasing the duration of phase 2 during the biphasic 25-joule shock all failed to successfully defibrillate the patient. The following options were considered: changing the RV lead position, adding a subcutaneous array, introducing an additional coil electrode in the coronary sinus or azygos vein, administering a potassium channel (IKr) blocking agent, such as dofetilide or sotalol, or applying epicardial patch electrodes via thoracotomy.
The RV lead had been placed 5 years ago in the RV apex, with successful defibrillation at 25 joules at that time. Electrical parameters had remained stable since implant. Revision would have required extraction of the old lead, with no guarantee that a non-apical RV lead position would provide superior defibrillation efficacy. Insertion of a coronary sinus coil also was undesirable as it risked possible dislodgement of the fresh LV pacing lead.
A single-element subcutaneous array (Model 6996 SQ, Medtronic Inc., Minneapolis, MN) was then placed in the recommended location along the left thorax. Despite this, defibrillation was not successful at 25 joules. Since the azygos vein courses posteriorly to the left ventricle, it was felt that a shocking coil placed in this location would provide an ideal shock vector.

Placement of coil in azygos vein

An 8-French straight-guide catheter (Attain Model 6218A, Medtronic) was introduced into the left subclavian vein and advanced to its junction with the SVC. A coronary vein subselection catheter (Attain Select II, Medtronic) with a right-angle tip was introduced through the guide catheter and used to direct a guidewire into the azygos vein.
Counterclockwise rotation of the subselector caused it to point posteriorly, and a small contrast injection confirmed engagement in the azygos vein orifice (Figure 2).

A 0.035-inch glidewire (Terumo Interventional Systems, Ann Arbor, MI) was introduced through the subselector distally into the azygos vein. Over this wire, the pliable subselector was advanced into the azygos vein down to the level of the diaphragm. Next, the 8-French guide catheter was passed over the subselector and the glidewire until it also reached the level of the diaphragm. The subselector was withdrawn, and a 7-French defibrillator lead (Riata ST Optim Model 7070, Figure 3: Chest radiograph, lateral view, obtained the day after the procedure. The star points to the location of the azygos vein lead in the chest. Note the position of left ventricle between the distal azygos vein coil and the distal right ventricular coil.)
St. Jude Medical, St. Paul, MN) was introduced into the guide catheter, which was then slit and removed. The distal coil of the Riata lead was used in tandem with the can as the cathode and the distal RV coil as the sole anode. The other Riata electrodes were capped. The ICD was connected to the leads using the above configuration, and defibrillation was successfully accomplished twice at 25 joules.

Discussion

Although uncommon, the inability to successfully defibrillate a patient with an ICD can be a vexing problem at initial implant or during generator replacement. In the absence of formal sequential defibrillation testing, a 10-joule safety margin between the successful shock and the maximum energy available in the device is considered adequate by convention.3–5

A number of patient factors have been shown to lead to elevated DFTs. These include male gender, high body mass index, increased LV mass due to LV hypertrophy or dilatation, and a wider QRS complex on surface electrocardiogram. Patients with hypertrophic cardiomyopathy, Brugada syndrome, or chronic kidney disease may be especially susceptible to elevated thresholds.1,3–8

Metabolic abnormalities such as hypoxia, hypercapnea, acidosis and electrolyte abnormalities can increase defibrillation energy requirements. Ischemia and repeated DFT testing also can lead to refractory ventricular fibrillation.9–12

A number of device-related factors also may impact energy requirements for defibrillation. Shock polarity may affect defibrillation efficacy. Early devices were designed with the RV distal coil as the cathode and the combination of an SVC coil and can as the anode. More recently, some evidence has emerged to support the notion that the creation of areas of hyperpolarization, and thereby the formation of virtual cathodes. These in turn initiated ventricular fibrillation.14 Biphasic shocks incorporate a second, reverse-polarity phase, which removes the residual hyperpolarization and leads to lower energy requirements. This has been quaintly termed “charge burping.”15

Shock duration (“pulse width”) and rate of charge decay (“tilt”) are other parameters that may influence defibrillation efficacy. Optimal pulse width and tilt may vary in individual patients, depending on the electrode tissue interface, impedance, and other factors. For example, when high thresholds are encountered in patients with prolonged repolarization due to amiodarone use, a longer pulse width is frequently more effective.9,10 Some manufacturers have introduced devices with a programmable pulse width and tilt (St. Jude, Biotronik), while these parameters are fixed in other devices (Medtronic, Boston Scientific). No head-to-head studies have been conducted to compare the superiority of programmable versus fixed pulse-width devices.11,12

The shock vector is important since the depolarizing current should traverse as large a portion of the ventricular mass as possible for efficient defibrillation. This is generally achieved with a triad of electrodes in the right ventricle, the SVC and the infracavitary fossa.1 An apical RV lead position appears to be superior to a septal or outflow tract location, as it allows for the flow of current through a major part of the right ventricle and left ventricle when the receiving electrodes are located in the SVC (proximal coil) and the infracavitary fossa (can), although some studies show no advantage with this choice of lead position.16–18 When the ICD is implanted in the right infracavitary fossa, an unfavorable vector is present. This may be alleviated by removing the can from the triad.18–20

In the present case, when all other configurations failed, a change in shock vector accomplished by adding the azygos vein coil, such that the entire mass of the left ventricle was encompassed between the electrodes, successfully lowered energy requirements to a level needed to achieve successful defibrillation (Figure 3).

Table 1: Factors that affect defibrillation thresholds

<table>
<thead>
<tr>
<th>Patient-related</th>
<th>Device related</th>
<th>Metabolic</th>
<th>Drugs</th>
<th>Procedure related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Shock vector</td>
<td>Hypoxia</td>
<td>Amiodarone</td>
<td>Connection reversal</td>
</tr>
<tr>
<td>Obesity</td>
<td>Shock polarity</td>
<td>Hypercapnea</td>
<td>Carvedilol</td>
<td>Loose set screw</td>
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<td>LVH w/o dilation</td>
<td>Shock waveforms,</td>
<td>Acidosis</td>
<td>Verapamil</td>
<td>Class I AAD</td>
</tr>
<tr>
<td>QRS duration</td>
<td>including monophasic</td>
<td>Hypothermia</td>
<td>Sildenafil</td>
<td>Lead fracture</td>
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<tr>
<td>HCM</td>
<td>versus biphasic device;</td>
<td>Ischemia</td>
<td>Venlafaxine</td>
<td>Pericardial effusion</td>
</tr>
<tr>
<td>Brugada syndrome</td>
<td>pulse width; and tilt</td>
<td>Repeated DFTs</td>
<td>Cocaine</td>
<td>Pneumothorax</td>
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<tr>
<td>CKD</td>
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<td>Hypokalemia</td>
<td>Prophylol</td>
<td>Pleural effusion</td>
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<tr>
<td>CHF</td>
<td>Lead location</td>
<td>Hyperkalemia</td>
<td>Antidepressants</td>
<td>Proximal coil in RA shunting current</td>
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<tr>
<td>Pleural effusion</td>
<td>Lead malfunction</td>
<td>Hypomagnesemia</td>
<td>Pocket hematoma</td>
<td>Lead malposition</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>Generator malfunction</td>
<td>Hypocalcemia and</td>
<td></td>
<td></td>
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<tr>
<td>Anxiolytics</td>
<td>Head air or fluid leak</td>
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</tbody>
</table>

AAD: antiarrhythmic drugs; CHF: congestive heart failure; CKD: chronic kidney disease; DFTs: defibrillation thresholds; HCM: hypertrophic cardiomyopathy; LVH: left ventricular hypertrophy; RA: right atrial.
Successful defibrillation, achieved using a shocking coil in the azygos vein, has been described previously, although not as a final resort when all non-thoracotomy options failed. The literature suggests that the procedure can be technically challenging. Modification of the tools used to introduce leads into the coronary vein branches simplified the implant considerably.

A practical approach to patients with elevated defibrillation energy requirements (Table 1)

- Check connections: inappropriate impedance may be a clue to a misconception or current shunting.
- Reverse defibrillation shock polarity.
- Rule out reversible causes (ischemia, hypothermia, drug effects, and metabolic abnormalities).
- Modify pulse width/tilt; if not programmable, disconnecting the SVC coil or can will increase impedance and prolong shock duration.
- Change the shock vector by using an additional coil in the azygos vein, coronary sinus, or subcutaneous array.
- Repeat defibrillation testing after administration of IKr channel blocker, like sotalol or dofetilide, as a last resort before thoracotomy.
- Apply defibrillation patches to the epicardium via thoracotomy.

Conclusion

The azygos vein is an attractive extracardiac target for placement of a shocking coil, as it provides an ideal shock vector. Tools designed for placing epicardial leads via the coronary sinus branches can be adapted to conveniently place the azygos vein coil.

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References