How to manage the patient with a high defibrillation threshold

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Introduction

Defibrillation threshold (DFT) testing is an integral part of implantable cardioverter-defibrillator (ICD) placement and follow-up. Unfortunately, the DFT can vary widely from day to day, influenced by many factors including electrolytes, sympathetic tone, antiarrhythmic drugs, and other medications. For this reason, a 10-J safety margin between the lowest successful defibrillation energy during testing and the maximal device output has been widely adapted as standard practice.[1]

Analysis of 1,139 patients undergoing DFT testing after ICD placement or revision at our institution demonstrated that 6.2% had unacceptably high DFTs. Although the majority of these patients were undergoing initial ICD placement, 37% were undergoing device revision, replacement, or upgrade.[2] Unfortunately, a significant percentage of patients with high DFTs die of sudden cardiac death, presumably due to inadequate defibrillation energy.[3] In experienced hands, more than 85% of these patients can undergo system modification that provides adequate safety margins.[2] In this article, we discuss therapeutic strategies to help manage patients with high DFTs.

Management options

Use of a high-output device

The most straightforward technique to manage a patient with a high DFT and inadequate safety margin is to replace a standard generator with a high-output generator. We empirically implant a high-output generator whenever DFT testing is not performed at implant or in patients who are expected to have an elevated DFT (e.g., patients receiving chronic amiodarone therapy or with hypertrophic cardiomyopathy). However, 48% of patients still required additional modification(s).[2] Use of a high-output device is a solution when it provides an adequate defibrillation safety margin (>10 J); however, it is not recommended as an empiric substitute for DFT testing unless testing cannot be safely performed.

Right ventricular lead location

Standard ICD placement involves lead placement with a distal electrode in the right ventricular (RV) apex and a proximal electrode in the superior vena cava (SVC)–right atrial (RA) junction. A more proximal location of the distal coil, either intentionally or because of lead dislodgment, can lead to an increase in DFT. A trial of a more apically located distal coil is warranted in the setting of a high DFT.

Repositioning the RV lead to the anterior high interventricular septum in the RV outflow tract (RVOT) is an alternative strategy that in one study was shown to lower DFTs without late RV lead dislodgment.[4]

Addition of a subcutaneous array

The addition of a subcutaneous (SQ) array is a common strategy for lowering DFT. Typically, after placing the RV lead and confirming a high DFT, a curved tunneling rod introducer is advanced through the standard infraclavicular incision into the SQ tissue until the tip rests inferior to the scapula and just lateral to the spine. Then the SQ array is advanced to this position through the introducer. This technique can be painful, and typically general anesthesia or deep sedation is needed. We have been able to successfully lower DFTs in 14% of patients using this approach.[2] In addition to improvement in DFTs, an impedance drop should be expected. In the event of improvement but still inadequate DFTs after SQ array placement, we have had anecdotal success with a second SQ array inferior to the first array connected with a Y-connector. This technique encompasses a more substantial segment of myocardium and allows further drop in impedance.

Repositioning of the proximal electrode

Single-lead, dual-electrode systems have effectively replaced dual-lead systems in standard practice. However, one

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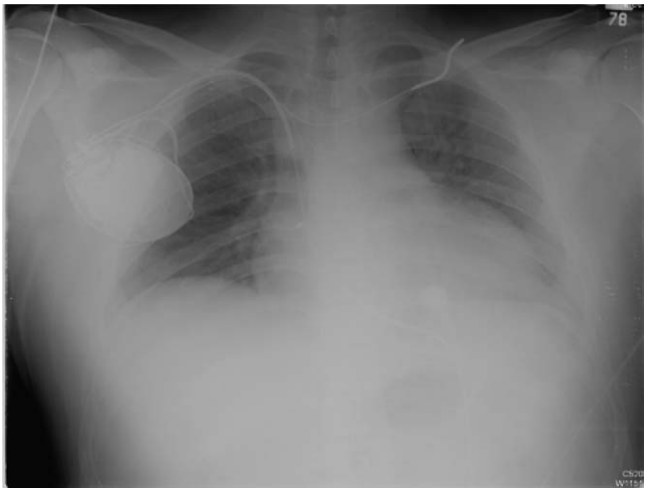

Figure 1 Right-sided defibrillator implant in a patient with hypertrophic cardiomyopathy. The patient's previous left-sided device, including the subcutaneous array, required explantation because of infection. The new right-sided device did not successfully defibrillate the patient despite removal of the superior vena cava coil. A proximal coil was placed in the left subclavian vein, resulting in defibrillation with an adequate safety margin.

of the limitations of the single-lead system is the fixed interelectrode distance between the distal and proximal coils. A two-lead system offers the advantage of an independent proximal electrode that can be variably positioned in the SVC or other structure. No study has demonstrated a universally superior proximal lead location. However, multiple studies have demonstrated significant improvement in DFTs in individual patients with placement of the proximal coil in the left subclavian vein[5] (Figure 1), brachiocephalic vein (Figure 2),[6,7] or azygos vein.[8]

Removal of the SVC coil

Standard practice consists of making the ICD configuration an "active" or "hot" can. However, at least one major device manufacturer allows removal of the can from the circuit. Use of a triad configuration including an active can and dual coil, single lead with electrodes in the RV apex and SVC–RA junction can significantly reduce DFTs. In select individuals with high DFTs, however, capping or removing the SVC coil, thus leading to a unipolar configuration, can lower DFTs. This strategy is particularly attractive in patients with low impedance ($<40\ \Omega$). This strategy was successful in 15% of patients with a high DFTs at our institution.[2]

Addition of a coronary sinus lead

Clinical studies have demonstrated that placement of a coil in a posterior or lateral branch of the coronary sinus (CS) can result in substantial (up to 45%) reductions in mean DFT. Whether an anterior left ventricular location is acceptable is unclear.[9] Although CS placement of a defibrillation lead appears promising, a current barrier is the limited number of models of defibrillation leads with sufficiently small diameters to successfully navigate the CS and its branches.

Changing polarity

Generally, using the distal coil as the cathode is the nominal setting for most ICDs; using the distal coil as the anode is the reverse configuration. The nominal configuration appears to be adequate for most patients; however, the DFT is lowered by 16% with the distal coil as the anode. In individual patients, substantial variability (up to 60%) in DFTs does exist using the nominal or the reverse configuration. We have found that reductions in DFTs that occur with polarity changes sometimes do not persist upon retesting.

Waveform

Adjustment to the tilt of the biphasic waveform is a viable option for managing high DFTs in some patients, although not all device manufacturers allow this option. Head-to-head comparisons of specific tilt configurations have not demonstrated an ideal "one size fits all" configuration. Protocols have been developed based on lead impedance and device capacitance observed during implantation to allow individual patient optimization. This type of optimization can lead to significant reductions in DFTs. Published tables assisting with tilt alteration are available to assist the implanter. The tables allow estimation of the optimal second phase duration, which ideally should be set slightly less than the passive membrane time constant.

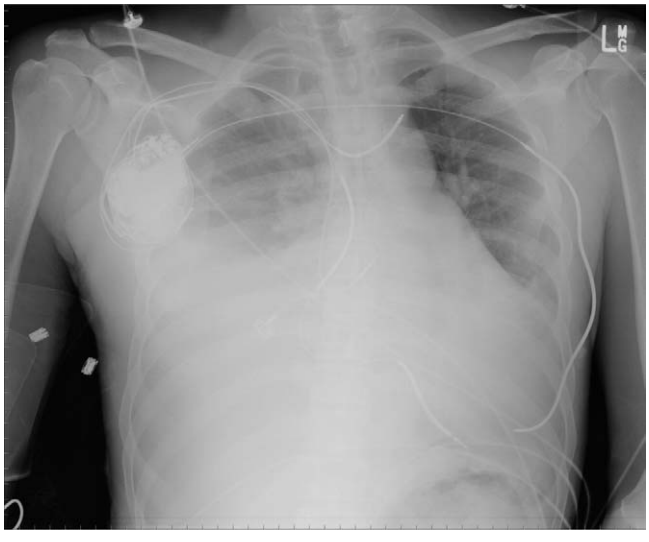

Figure 2 Right-sided defibrillator in a patient with dilated cardiomyopathy and end-stage renal disease with a hemodialysis shunt on the left. Defibrillation failed despite changes in polarity and removal of the superior vena cava coil. Defibrillation also failed after placement of a proximal coil in the left brachiocephalic vein (shown). An adequate safety margin ultimately was obtained after placement of a left-sided subcutaneous array (shown).

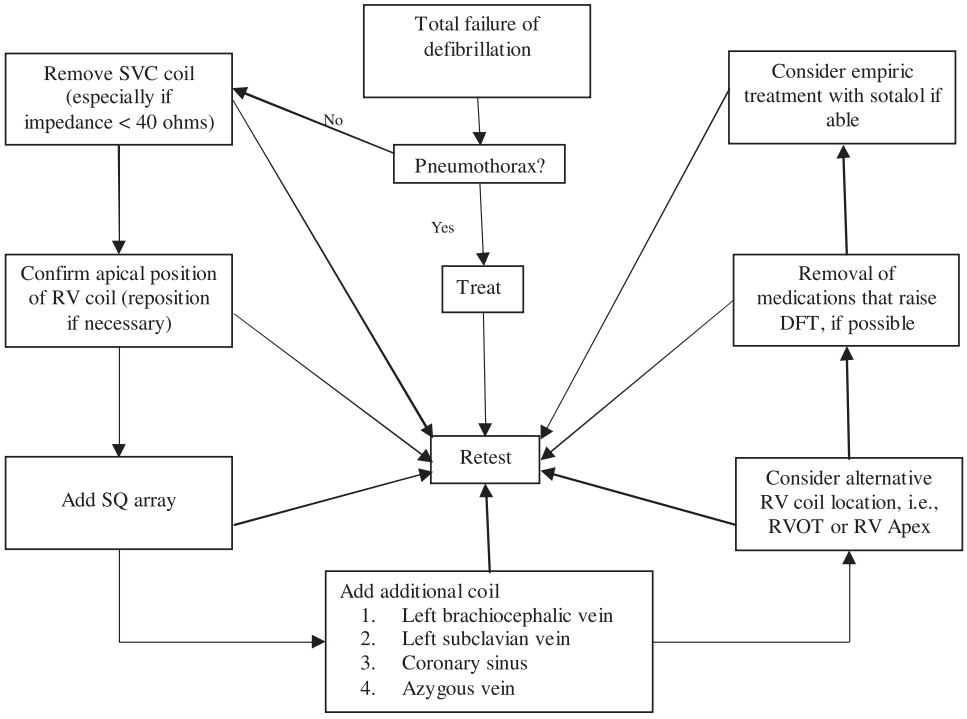

Figure 3 Suggested management algorithm for the patient with a high defibrillation threshold (DFT) and failure of the initial and maximal output shocks. After ruling out pneumothorax, the implanter is advised to attempt modifications as outlined, with frequent retesting to assess success. RV = right ventricular; RVOT = right ventricular outflow tract; SQ = subcutaneous; SVC = superior vena cava.

Other considerations

Pneumothorax

Pneumothorax is a complication of pectoral device implantation but a relatively unrecognized cause of high DFTs during device implantation. A high DFT with high impedance should prompt a careful evaluation to rule out pneumothorax, even if traumatic vein cannulation did not occur. Whether DFT elevation is proportional to the size or location of the pneumothorax is unclear. In addition to the standard postprocedure chest x-ray film, we recommend inspection of the thorax with fluoroscopy during the procedure to assist early detection of this complication.

Medications

A complete list of medications affecting the DFT is beyond the scope of this article; however, some medications are worth mentioning. Mexiletine, carvedilol, sildenafil, and venlafaxine have been shown to increase DFTs. Propafenone does not significantly alter the DFT, whereas dofetilide appears to lower the DFT. Chronic amiodarone use has demonstrated increased or no change in DFTs. We have observed a threefold increase in the risk of high DFTs among patients taking amiodarone.[2]

Sotalol lowers the DFT and has potential therapeutic use in the management of patients with high DFT. We have used sotalol successfully in some patients with high DFTs. No clear dosing guidelines exist, although dosages ranging from 40 to 320 mg twice per day have been used successfully.

Prolonged DFT testing

Prolonged DFT testing can cause transient ventricular dysfunction, particularly in patients with a reduced baseline ejection fraction. In addition, testing, anesthetic agents, potential myocardial damage or ischemia, and variable neural activation can lead to alterations in sympathetic tone, thereby leading to dramatic increases in DFTs. This situation probably is easiest to recognize when previously effective shocks no longer reliably defibrillate later during the procedure. When this occurs, repeat DFT testing at a later time is appropriate.

Approach to the patient with a high DFT

No universal solution exists to treat the patient with a high DFT. Therefore, a rational, empiric approach of trial-and-error testing is necessary to find the appropriate solution. Our standard testing protocol involves two defibrillation attempts at least 10 J lower than the maximum output of the device with a rescue shock, as necessary, at the maximum output. In the event of defibrillation failure with the initial and maximum output shocks, substantial modifications generally are needed (Figure 3). In the event of defibrillation

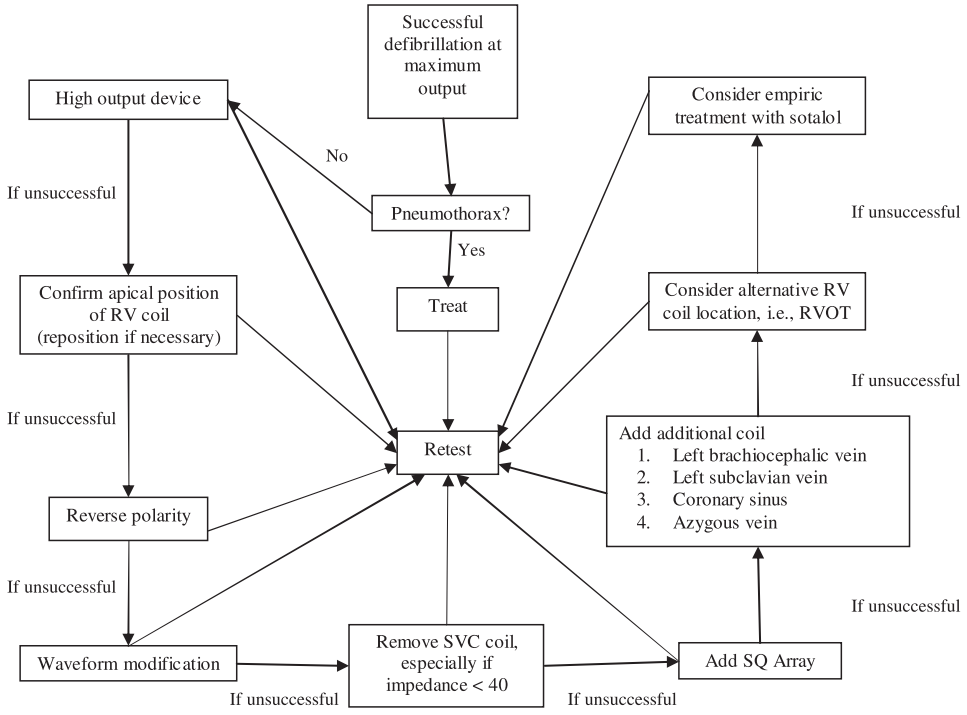

Figure 4 Suggested management algorithm for the patient with a high defibrillation threshold and failure of the initial shock with successful rescue shock at maximum output. After ruling out pneumothorax, the implanter is advised to attempt modifications as outlined, with frequent retesting to assess success. RV = right ventricular; RVOT = right ventricular outflow tract; SQ = subcutaneous; SVC = superior vena cava.

failure with the initial shock and subsequent successful rescue with a maximal energy shock, a wider array of modifications likely will be successful (Figure 4).

Conclusion

Patients with high DFTs represent a small but significant portion of the population with ICDs. With the rapidly growing number of patients receiving ICDs, the number of patients with unacceptably high DFTs undoubtedly will increase We have outlined an approach that can be used to achieve an adequate safety margin in the majority of patients.

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