Evaluation and Management of Patients After Implantable Cardioverter-Defibrillator Shock

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SUDDEN CARDIAC DEATH (SCD) is often the end result of fatal ventricular arrhythmias, including ventricular fibrillation or monomorphic or polymorphic ventricular tachycardia (VT). The only effective approach to preventing SCD resulting from ventricular arrhythmias is rapid electrical defibrillation. With the pioneering work of Michel Mirowski, the first automatic implantable cardioverter defibrillator (ICD) was implanted in 1980. In the ensuing 25 years, there has been a tremendous increase in the use of ICDs after several large clinical trials demonstrated their ability to effectively reduce mortality in selected populations of patients with cardiac disease. Given the tremendous increase in the use of ICDs, the nonelectrophysiologist will often encounter patients who have received an ICD shock. In this review, we will present an evidence-based discussion of the evaluation and management of the patient who presents with an ICD shock.

EVIDENCE ACQUISITION
We conducted a literature search using the PubMed and MEDLINE databases to identify articles published from January 1990 to September 2006, using the Medical Subject Headings defibrillators, implantable; defibrillators, implantable/adverse effects; anti-arrhythmic agents; electric countershock; quality of life; tachycardia therapy; algorithm; ventricular tachycardia/diagnosis; and supraventricular tachycardia/diagnosis. Case reports were excluded and articles were limited to those published in English. Scientific statements and guidelines from the American College of Cardiology, the American Heart Association, and the Heart Rhythm Society were also reviewed, as were the reference lists of retrieved articles, to identify any additional articles for inclusion.

Evidence Synthesis There are multiple causes of both appropriate and inappropriate ICD shocks. Irrespective of appropriateness, receiving ICD shocks substantially impairs a patient’s quality of life. A variety of techniques are available using ICD programming to reliably limit the occurrence of appropriate or inappropriate ICD shocks. Antiarrhythmic medications can also effectively reduce the occurrence of shocks.

Conclusions Through the use of effective ICD programming and antiarrhythmic medications, the occurrence of ICD shocks can be reduced while maintaining the lifesaving ability of the ICD. A basic understanding of the range of available options is fundamental for evaluation and management of the patient who has received an ICD shock.

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EVIDENCE SYNTHESIS

Overview of the ICD

An ICD (FIGURE 1) is made up of a pulse generator, sensing/pacing electrodes, and defibrillation coils. The pulse generator contains a microprocessor to control the analysis of cardiac rhythm and delivery of therapy, a memory component to store electrocardiographic data, a high-voltage capacitor, and a battery. An electrode is generally transvenously placed at the endocardium of the right ventricular apex or, rarely, surgically placed on the epicardium. Dual-chamber ICDs have an additional electrode usually placed in the right atrial appendage. Biventricular ICDs have a third electrode placed transcutaneously in a branch off of the coronary sinus or surgically on the epicardium of the left ventricle. Defibrillation coils are positioned on the right ventricular electrode at the level of the superior vena cava and the right ventricle. In most ICD systems, the pulse generator serves as part of the defibrillation pathway; thus, current flows from the distal defibrillation coil simultaneously to the device and to the proximal defibrillation coil.

In addition to pacing for bradycardia, ICDs can deliver multiple types of therapy when a ventricular arrhythmia is detected, including antitachycardia pacing, low-energy cardioversion (eg, 5 J), and high-energy defibrillation (eg, 35 J). These therapies can be tailored to tachycardias in multiple rate tiers, allowing for different treatments for different types of tachycardia. Multitiered therapy helps reduce the need for high-energy defibrillation without compromising ICD efficacy (TABLE 1).

Causes of an ICD Shock

The purpose of an ICD is to treat potentially life-threatening malignant ventricular arrhythmias. This is accomplished with appropriate antitachycardia pacing or shock therapy from the ICD. However, inappropriate therapy can be a relatively frequent occurrence. In a review of the 449 patients randomly assigned to receive ICD therapy in the Antiarrhythmics Versus Implantable Defibrillators (AVID) trial, 22% of patients received inappropriate therapy primarily for atrial fibrillation or other supraventricular tachycardias. Of 778 patients implanted with an ICD and undergoing follow-up for an average of 4 months, Rosenqvist et al found that 102 patients (13%) received inappropriate ICD therapies. While misdiagnosis of atrial fibrillation or other supraventricular tachycardias is the cause for most episodes of inappropriate ICD therapy, a variety of other mechanisms, including lead failure, electromagnetic interference, and oversensing of diaphragm myopotentials or T waves, can result in inappropriate diagnosis and therapy by the ICD (Box). Examples of appropriate and inappropriate ICD shocks are shown in Figure 2.

Effect of ICD Shocks on Quality of Life

While the ICD may improve survival in select patient populations, the benefit may be obscured by a diminished quality of life (QOL). In a substudy of the Coronary Artery Bypass Graft Patch (CABG Patch) trial, Namerow et al...
measured QOL in 490 patients, half of whom were randomly assigned to receive an ICD. At follow-up, patients in the ICD group who received ICD shocks reported feeling less healthy, had reduced physical and emotional role functioning, and had lower levels of psychological well-being. Similar findings emerged from the Canadian Implantable Defibrillator Study (CIDS) and the AVID trial comparing the benefit of ICDs vs antiarrhythmic medications. Irvine et al assessed QOL at 6 months and 12 months in 317 CIDS participants and showed that emotional and physical health scores were improved in the ICD group compared with the amiodarone group but not in those who received multiple shocks. Schron et al measured QOL over 1 year of follow-up in 800 patients randomly assigned to receive ICD or antiarrhythmic medications in the AVID trial. The occurrence of ICD shocks was associated with decreased physical function and mental well-being and with increased patient concerns. In a cohort study of patients with ICDs, patients who received an ICD shock were found to be more anxious than those who had not received a shock, particularly in regard to the ability to perform daily activities. This anxiety may even manifest as panic disorder or agoraphobia.

Clearly, as demonstrated by a survey of clinicians regarding QOL in ICD recipients, attention needs to be paid to managing the emotional well-being of ICD recipients who have a history of ICD shocks. When a patient presents with 1 or more ICD shocks, the cause of the shock should be explained to the patient. Reassurance and psychological support are critical. The appropriate use of anxiolytic medications may be necessary. While a small study by Kohn et al has shown that cognitive behavioral therapy may alleviate the depression, anxiety, and difficulty with adjustment found among ICD recipients, more investigation is needed in this area. In this regard, it becomes imperative to take steps to limit the occurrence of both appropriate and inappropriate ICD shocks.

ICD Programming to Reduce Appropriate ICD Shocks
Antiarrhythmia or overdrive pacing is the first therapy generally programmed for episodes of spontaneous VT. With antiarrhythmia pacing, an ICD treats an episode of spontaneous VT either with a burst of ventricular paced beats at a rate slightly faster than the VT rate or with a rapidly decelerating train of ventricular paced beats. This train of paced beats collides with the ongoing arrhythmia circuit, often terminating the arrhythmia. Following initial reports of the efficacy of antiarrhythmia pacing compared with that of low-energy cardioversion, multiple studies further demonstrated the clear efficacy of antiarrhythmia pacing to terminate spontaneous VT, thereby avoiding appropriate ICD shocks. Large-scale studies have shown antiarrhythmia pacing to effectively terminate 90% to 96% of episodes of spontaneous VT.

Initially there had been concern that antiarrhythmia pacing should not be used for the treatment of fast VT (heart rate > 180/min) due to a fear of low efficacy and a theoretical risk of rate acceleration. However, these concerns were allayed with the results of the Pacemaker Tachycardia Study II trial, in which 634 patients with ICDs were randomly assigned to receive empirical antiarrhythmia pacing or shock therapy for the initial treatment of spontaneous fast VT. At 11 months’ follow-up, antiarrhythmia pacing was shown to successfully terminate 81% of episodes of fast VT. Antiarrhythmia pacing is highly effective at preventing the need for appropriate shock therapy in the majority of cases of VT, thereby reducing patient discomfort and patient distress as well as battery drain.

ICD Programming to Reduce Inappropriate ICD Shocks
Misinterpretation of supraventricular tachycardias such as sinus tachycardia or atrial fibrillation by the ICD is the most common cause of inappropriate ICD shocks. Successive generations of ICDs have incorporated increasingly sophisticated algorithms to discriminate VT from supraventricular tachycardias to reduce the occurrence of inappropriate shocks. As specified in the multiterritorial programming of an ICD, all ICDs use the ventricular rate as the first criterion for the detection of VT or ventricular fibrillation. To be considered an arrhythmic episode, the ICD will, for instance, look for a prespecified number of consecutive ventricular sensed events occurring faster than the rate cutoff to exclude nonsustained arrhythmias or frequent premature ventricular complexes.

Onset. To distinguish sinus tachycardia from VT, nearly all ICDs can be

| Box. Causes of Appropriate and Inappropriate Implantable Cardioverter-Defibrillator Shocks |
| Causes of Appropriate Shocks |
| Ventricular fibrillation |
| Monomorphic ventricular tachycardia |
| Polymorphic ventricular tachycardia |
| Torsades de pointes |
| Causes of Inappropriate Shocks |
| Atrial fibrillation |
| Atrial flutter |
| Atrial tachycardia |
| Supraventricular tachycardia |
| Junctional tachycardia |
| Sinus tachycardia |
| Multiple premature ventricular contractions |
| Oversensing of T waves |
| Double counting of QRS complex |
| Oversensing due to lead failure or insulation break |
| Oversensing of diaphragmatic myopotentials |
| Electromagnetic interference |
programmed to implement a sudden-onset algorithm to detect a sudden increase in the ventricular rate at the onset of the tachycardia. Several clinical studies have demonstrated a sudden-onset criterion to be extremely effective at excluding sinus tachycardia from ICD therapy while retaining nearly 100% sensitivity for VT.23-26 The sensitivity for VT by a sudden-onset criterion may be lower when there is a slight change in rate from sinus rhythm to VT, as in the occurrence of VT during exercise.26

Stability. For discrimination of VT from atrial fibrillation, most ICDs can be programmed to use a ventricular rate stability criterion because the ventricular rate during atrial fibrillation is generally more unstable than during VT. A stability criterion is highly effective for excluding atrial fibrillation from inappropriate therapy, particularly at slower ventricular rates.23-27 However, at higher rates, atrial fibrillation may become more regular and more difficult to distinguish from VT.

Morphology. Morphologic discrimination takes advantage of the difference in appearance of the local electrogram sensed by the ventricular lead when it originates in the ventricle rather than traveling through the normal conduction system. With all such algorithms, electrograms obtained during episodes of tachycardia are compared with a stored electrogram obtained during sinus rhythm. While not all ICDs will incorporate morphologic discrimination, such ICD programming can be very effective at discriminating VT from supraventricular tachycardias.28-30

AV Relationship
A dual-chamber ICD can be programmed to take advantage of atrial sensing capabilities to enhance discrimination of VT from supraventricular tachycardias. Simply looking for a tachycardia with AV dissociation, in which the ventricular rate exceeds the atrial rate, will properly distinguish a large majority of ventricular from supraventricular tachycardias. However, this criterion will fail when there is a 1:1 relationship between the atrial and ventricular rates or in the case of dual tachycardias, such as the case of VT with concomitant atrial fibrillation. In these situations, ICDs may use sophisticated algorithms analyzing the relationship between sensed atrial and ventricular activity to diagnose the tachycardia.31-33

Although a dual-chamber ICD theoretically should help with arrhythmia diagnosis to reduce the occurrence of inappropriate shocks, when rigorously studied the benefit is not so clear. Several randomized, prospective studies comparing single-chamber vs dual-chamber ICDs have shown no benefit of dual-chamber ICDs in reducing inappropriate shocks.34-36 Although a larger randomized crossover study of 400 patients comparing single-chamber with dual-chamber ICD detection algorithms demonstrated a nearly 50% reduction in the rate of inappropriate detection when using a dual-chamber algorithm,37 the use of a

**Figure 2.** Examples of Appropriate and Inappropriate Implantable Cardioverter-Defibrillator (ICD) Shocks

**A** Schematic of ICD electrocardiographic data based on that from a patient with dilated cardiomyopathy. P indicates atrial-sensed events; R, ventricular-sensed events. Atrioventricular dissociation during rapid ventricular tachycardia is shown early in the tracing with subsequent resumption of sequential atrioventricular activity after successful defibrillation by an appropriate ICD shock.

**B** Schematic of ICD electrocardiographic data based on that from a patient with ischemic cardiomyopathy and a history of resuscitated ventricular tachycardia. Noise in the ventricular lead is misinterpreted as ventricular fibrillation leading to an inappropriate ICD shock.
dual-chamber ICD in patients with a standard indication for a single-chamber ICD to reduce the occurrence of inappropriate shocks remains controversial.

**Combined Algorithm Performance**
Each major manufacturer of ICDs uses a different combination of the above techniques for diagnosis of tachycardias. In general, the performance of the discrimination algorithms from the major manufacturers are comparable (Table 2). However, specific ICD programming can and should be tailored to a patient’s specific needs based on the patient’s indication for an ICD, cardiac disease history, and tendency for inappropriate therapy.

**Medications to Reduce ICD Shocks**
After several large randomized trials proved the superiority of ICD treatment over therapy using antiarrhythmic medications for the prevention of SCD, the use of antiarrhythmic medications for primary treatment of patients at risk for SCD quickly diminished. However, antiarrhythmic medications are often initiated in patients with ICDs to reduce the frequency of defibrillator shocks. Antiarrhythmic medications can reduce the frequency of ICD shock by reducing the tendency for sustained VT; by slowing of episodes of spontaneous VT, thus rendering such episodes more amenable to antitachycardia pacing; and by suppressing atrial tachyarrhythmias that lead to inappropriate therapy or that can even trigger ventricular tachyarrhythmias.

Two studies have investigated the efficacy of racemic sotalol compared with placebo in reducing the frequency of ICD shocks. In a study of 93 patients with ICDs who were randomly assigned to receive sotalol or no antiarrhythmic medication, sotalol was found to reduce the incidence of recurrent sustained ventricular tachyarrhythmias. In a multicenter trial, 302 patients with ICDs were randomly assigned to treatment with sotalol or placebo. At 12 months’ follow-up, treatment with sotalol was found to lower the risk of death or delivery of an ICD shock. However, in a study of 100 patients comparing the efficacy of metoprolol or sotalol, there was no difference in the incidence of appropriate ICD therapies at approximately 2 years’ follow-up.

The efficacy of azimilide, a novel class III antiarrhythmic medication, has been demonstrated in 2 studies. In a dose-finding placebo-controlled study of 172 patients with ICDs, appropriate ICD therapies were significantly reduced at all doses of azimilide studied. These findings were confirmed in a large, placebo-controlled, randomized clinical trial of azimilide, the Shock Inhibition Evaluation With Azimilide (SHIELD) study, in which Dorian et al randomized assigned 633 ICD recipients to receive placebo or azimilide (75 or 125 mg). At 12 months’ follow-up, the incidence of appropriate ICD therapies (shock or antitachycardia pacing) was significantly reduced with both azimilide doses.

Most recently, in the multicenter, international Optical Pharmacological Therapy in Cardioverter Defibrillator Patients (OPTIC) study, 412 patients with ICDs were randomly assigned to receive treatment with a β-blocker alone, amiodarone plus β-blocker, or sotalol. At 1-year follow-up, amiodarone plus β-blocker was the most effective regimen at reducing ICD shocks. The shock rate at 1 year was 38.5% in the β-blocker group, 24.3% in the sotalol group, and 10.3% in the amiodarone plus β-blocker group. Adverse events, including pulmonary toxicity, were, however, more common in patients randomly assigned to receive amiodarone.

Interestingly, there are emerging data that statins may have antiarrhythmic effects and may reduce the occurrence of ICD shocks. In a substudy of the Multicenter Automatic Defibrillator Implantation Trial (MADIT II), patients in the ICD group taking statins for 90% or more of days of follow-up compared with those with lower statin usage had a reduced incidence of appropriate ICD therapies. The implications of this observation remain unclear and will need to be confirmed in large prospective studies.

When considering the use of antiarrhythmic medications in patients with ICDs, it is critical to consider the risk of adverse events. The most important potential risk is the possibility of increasing the ventricular defibrillation threshold, meaning that an ICD shock is less likely to successfully terminate an arrhythmia. This is unlikely in the cases of sotalol or azimilide, which have no effect or may even lower the defibrillation threshold. In the case of amiodarone, however, defibrillation threshold can increase and may need reevaluation. However, recent data from the OPTIC trial suggest that reevaluation may not be necessary. In addition, antiarrhythmic medications can be proarrhythmic. Sotalol in particular, compared with amiodarone or azimilide, is associated with a higher risk of torsades de pointes. Finally, the noncardiac adverse effects of antiarrhythmic medications must be considered. Specifically, amiodarone is asso-

### Table 2. Performance of Integrated Programming in Dual-Chamber Implantable Cardioverter-Defibrillators From Major Manufacturers to Distinguish Ventricular Tachycardia from Supraventricular Tachycardia

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Biotronik</th>
<th>ELA Medical</th>
<th>Guidant</th>
<th>Medtronic</th>
<th>St Jude Medical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Sinha et al</td>
<td>Sadoul et al</td>
<td>Kouasen et al</td>
<td>Wilkoff et al</td>
<td>Bailin et al</td>
</tr>
<tr>
<td>No. of patients</td>
<td>209</td>
<td>95</td>
<td>51</td>
<td>933</td>
<td>107</td>
</tr>
<tr>
<td>Study duration</td>
<td>10 mo</td>
<td>15 mo</td>
<td>12 mo</td>
<td>3.9 mo</td>
<td>68 d</td>
</tr>
<tr>
<td>Ventricular tachycardia</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sensitivity, %</td>
<td>100</td>
<td>99.3</td>
<td>99</td>
<td>99.9</td>
<td>100</td>
</tr>
<tr>
<td>Specificity, %</td>
<td>89</td>
<td>89.2</td>
<td>89</td>
<td>66.6</td>
<td>84</td>
</tr>
</tbody>
</table>

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associated with a multitude of potential adverse effects, including pulmonary and thyroid toxicity.

Based on the above evidence, a reasonable approach to the use of antiarrhythmic medications in patients with ICDs would be to first use β-blockers in all patients with ICDs, whether for primary or secondary prevention, unless contraindicated. In patients with recurrent ICD shocks, sotalol or amiodarone are reasonable first options. Sotalol is contraindicated in patients with uncontrolled heart failure and left ventricular dysfunction and should be used with caution in patients with renal impairment. Amiodarone has many potential noncardiac adverse effects and may require a reevaluation of the defibrillation threshold in patients with a high baseline threshold; nonetheless, it is the drug of choice in patients with heart failure and severe left ventricular dysfunction. Azimilide is not approved in the United States by the Food and Drug Administration. All other antiarrhythmic medications have minimal clinical data available and should be used as second-line therapy in patients not responding to amiodarone.

**Electrical Storm**

Electrical storm is defined as the occurrence of 3 or more episodes of a sustained ventricular arrhythmia within a 24-hour period. When this occurs in a patient with an ICD, the patient can present after receiving repetitive shocks or antitachycardia pacing from the device. Electrical storm is a common occurrence, with a reported incidence of 10% to 20%.38-62

There are limited data on the management of electrical storm. Initially, it is important to rule out potentially reversible triggers such as electrolyte imbalance, tricyclic overdose, or myocardial ischemia. Among the antiarrhythmic medications, amiodarone is generally considered the first choice based on its proven benefit in the treatment of cardiac arrest due to ventricular fibrillation.63 Beyond amiodarone, sympathetic blockade with oral or intravenous β-blocking medications, or even left stellate ganglionic blockade, may be critical to suppress the adrenergic drive, which can stimulate recurrent ventricular arrhythmias.64 Class I antiarrhythmic medications are often used but may be less effective than amiodarone or β-blockers.62,64 Sedation can assist in controlling electrical storm,65 and propofol, in particular, may have antiarrhythmic properties.66 Overdrive pacing using the ICD is a simple maneuver that can be quite effective.67,68 Emergent catheter ablation is generally reserved as a last resort.69,70 Finally, full hemodynamic support using a ventricular assist device, or cardiac transplantation, may be the only options in some patients.

It is important to note that while the ICD is a life-sustaining treatment that can save and prolong a meaningful life, in some situations the ICD can prolong a life overcome with suffering leading to an inevitable death. In such situations, it is essential to take note of a request from a patient or their surrogate to discontinue ICD therapy. Such a request can be considered analogous to a request to discontinue other life-sustaining interventions such as mechanical ventilation, renal dialysis, or artificial nutrition. When deliberating such a request, it is imperative that alternatives be fully discussed, psychiatric disorders that may distort judgment be excluded, and specific preparation be made for palliative care once ICD therapy is discontinued.71

**Bringing It All Together**

The management of a single ICD shock does not necessarily require an emergent office or emergency department visit (FIGURE 3). Although an ICD shock can be a frightening experience for the patient, occasional shocks are to be expected. When a single shock occurs, the physician should reassure the patient and refer him or her to a clinical electrophysiologist for evaluation within the week. However, if the shock is preceded or associated with syncope, shortness of breath, persistent palpitations, or chest pain, an emergency department visit is required. In these cases the physician must consider the possibility that an arrhythmic process might have been triggered by a change in the clinical status of the patient, such as active coronary disease, worsening heart failure, or electrolyte imbalance.

At the time of evaluation by the electrophysiologist, the appropriateness of ICD therapy can be determined by evaluation of the stored electrograms using a programmer made by the ICD manufacturer. The manufacturer can usually be determined by asking the patient (patients are instructed to carry documentation with them) or by examining medical records documenting ICD implantation. In the event that an electrophysiologist is not available, 24-hour technical support is provided by device manufacturers. Representatives from the device manufacturer, in the presence of a physician, may assist in evaluating the reason for an ICD shock.

In the case of an appropriate shock, a general assessment of the reason for the shock may reveal clinical deterioration, a change in medical therapy, or electrolyte imbalance, which should be addressed. However, when no cause for the ICD shock is evident, simply reassuring the patient regarding the effectiveness of the ICD therapy may be all that is required. In patients who present with frequent albeit isolated appropriate ICD shocks, clinicians may consider optimizing the programming of antitachycardia pacing, administering an antiarrhythmic medication as outlined above, or both.

In the case of an inappropriate ICD shock due to supraventricular tachycardia, adjustment of ICD detection zones or optimization of ICD discrimination features by an electrophysiologist may be helpful. Treatment of recurrent supraventricular tachycardia either by antiarrhythmic medications or by catheter ablation may also be helpful. Other causes of inappropriate shocks are often treated by ICD programming or lead revision in the case of lead malfunction.
The patient who experiences multiple ICD shocks over a short period always requires immediate medical attention, including cardiac monitoring in the emergency department. Telemetry observed at the time of an ICD-delivered therapy generally can help clinicians determine the appropriateness of the therapy.

In the conscious patient receiving multiple ICD shocks, the history can be helpful in suggesting the appropriateness of the shocks. For example, multiple separate shocks (occurring hours apart) while the patient is at rest usually signify recurrent successfully treated ventricular arrhythmias and thus are appropriate. On the other hand, multiple repetitive shocks (occurring within seconds or minutes of the previous shock) in the alert patient during intense physical activity are usually inappropriate; for example, a patient who experiences shocks during exercise may be receiving therapy for sinus tachycardia. The presence of fever or pain prior to shocks may also suggest inappropriate therapy for sinus tachycardia, whereas a shock associated with repetitive movements may suggest an inappropriate therapy due to lead malfunction. A shock preceded by chest pain, shortness of breath, or syncope is more likely an appropriate shock; hence, in the emergency department it is important to ascertain associated symptoms preceding the shock, as these may signify a change in clinical status that needs to be addressed.

Changes in the medication regimen can lead to ICD shocks by altering the QT interval or causing electrolyte imbalance. Levels of electrolytes, including potassium and magnesium, should be checked and corrected. A chest radiograph should be obtained to look for lead fracture or dislodgement. An electrocardiogram can offer clues as to a new ischemic event or prolongation of the QT interval. Finally, the electrograms stored in the ICD should be evaluated by the clinical electrophysiologist for ultimate diagnosis of the appropriateness of therapy.

In a patient experiencing multiple inappropriate ICD shocks, the device can be immediately disarmed by placing a magnet over the ICD pocket until it can be reprogrammed by the electrophysiologist. In a patient experiencing electrical storm and receiving multiple appropriate ICD shocks, antiarrhythmic medication, usually amiodarone, should be instituted while potentially reversible causes are addressed. A patient receiving multiple shocks will also often benefit from intravenous anxiolytics, as outlined above, to allay distress and potentially prevent arrhythmia recurrence. Bail-out options for refractory cases include general anesthesia, emergent catheter ablation, full hemodynamic support with a ventricular assist device, or cardiac transplantation.

Finally, in any patient receiving an ICD shock, attention must be paid to the patient’s psychological well-being. As described above, in patients who receive an ICD shock, particularly multiple ICD shocks, QOL is almost assured.
edly diminished and anxiety over the ability to perform routine daily activities is heightened. It may be important to consider anxiotics, support groups, or even individualized cognitive behavioral therapy or pharmacological intervention to address the patient's psychosocial needs. 72

CONCLUSION

With the recent tremendous increase in the use of ICDs, more nonelectrophysiologists will encounter the patient who has received an ICD shock. We have provided an evidence-based review of the evaluation and management of such patients. Although the ICD can be a lifesaving intervention, many patients will present with multiple appropriate and inappropriate shocks, which can profoundly diminish a patient's quality of life. However, through the use of effective ICD programming and antiarrhythmic medications, the occurrence of ICD shocks can be reduced while maintaining the lifesaving ability of the ICD. A basic understanding of the range of available options is fundamental for evaluation and management of the patient who has received an ICD shock.

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REFERENCES


hancements for implantable defibrillator rhythm di-
38. Sinha AM, Stellbrink C, Schuchert A, et al. Clini-
cal experience with a new detection algorithm for dif-
ferentiation of supraventricular from ventricular ta-
performance of a dual-chamber cardioverter defibril-
lator programmed with nominal settings: a European
13:29-32.
of a dual-chamber implantable defibrillator al-
gorithm for discrimination of ventricular from su-
41. Balln SJ, Niebauer M, Tomassoni G, Leman R. Clin-
ical investigation of a new dual-chamber implantable
cardioverter defibrillator with improved rhythm dis-
42. Hintringer F, Deibl M, Berger T, Paching O, Roithinger FX. Comparison of the specificity of
implantable dual chamber defibrillator detection
algorithms. Pacing Clin Electrophysiol. 2004;27:976-
982.
43. Kuck KH, Cappato R, Siebels J, Ruppel R. Ran-
domized comparison of antiarrhythmic drug therapy
with implantable defibrillators in patients resuscit-
ted from cardiac arrest: the Cardiac Arrest Study
44. Connolly SJ, Gent M, Roberts RS, et al. Cana-
dian Implantable Defibrillator Study (CIDS): a ran-
domized trial of the implantable cardioverter defibril-
lator against amiodarone. Circulation. 2000;101:1297-
1302.
45. Antiarrhythmics Versus Implantable Defibrilla-
tors (AVID) Investigators. A comparison of antiar-
rhythmic drug therapy with implantable defibrillators
in patients resuscitated from near-fatal ventricular
46. Stein KM, Euler DE, Mehr A, et al. Do atrial ta-
chyarrhythmias beget ventricular tachyarrhythmias in
defibrillator recipients? J Am Coll Cardiol. 2002;40:339-
340.
47. Kuhlkamp V, Mewis C, Merri M, Bosch RF, Seipel
L. Suppression of sustained ventricular tachyarrhyth-
my: a comparison of d,l-sotalol with no antiarrhyth-
mic drug treatment. J Am Coll Cardiol. 1999;33:
46-52.
48. Pacifico A, Hohnloser SH, Williams JH, et al; d,l-
Sotalol Implantable Cardioverter-Defibrillator Study
Group. Prevention of implantable defibrillator shocks
1895-1862.
49. Kettering K, Mewis C, Dornberger V, Vonthein
R, Bosch RF. Kuhlkamp V. Efficacy of metoprolol and
sotalol in the prevention of recurrences of sustained
ventricular tachyarrhythmias in patients with an im-
plantable cardioverter defibrillator. Pacing Clin
50. Singer I, Al-Khalidi H, Nizai I, et al. Azimilide de-
creases recurrent ventricular tachyarrhythmias in pa-
51. Dorian P, Borggreve M, Al-Khalidi HR, et al. Pla-
cebo-controlled, randomized clinical trial of azimilide
for prevention of ventricular tachyarrhythmias in pa-
tients with an implantable cardioverter defibrillator.
52. Connolly SJ, Dorian P, Roberts RS, et al. Com-
parison of beta-blockers, amiodarone plus beta-
blockers, or sotalol for prevention of shocks from
53. Vyas AK, Guo H, Moses AJ, et al. Reduction in ven-
tricular tachyarrhythmias with statins in the Multi-
center Automatic Defibrillator Implantation Trial
54. Manz M, Jung W, Luderitz B. Interactions be-
55. Jung W, Manz M, Pizulli L, Pfeiffer D, Luderitz
B. Effects of chronic amiodarone therapy on defibril-
56. Page RL. Effects of antiarrhythmic medication on
implantable cardioverter-defibrillator function. J Am
57. Wolbrette DL. Risk of proarrhythmia with class
III antiarrhythmic agents: sex-based differences and
58. Verma A, Kilicaslan F, Marroche NF, et al. Preva-
ience, predictors, and mortality significance of the caus-
ative arrhythmia in patients with electrical storm. J Car-
dence and clinical significance of multiple consecu-
tive, appropriate, high-energy discharges in patients
presages nonsudden death: the Antiarrhythmics Ver-
sus Implantable Defibrillators (AVOID) trial. Circulation.
2001;103:2066-2071.
61. Aya A, Haghjoo M, Dehghani MR, et al. Preva-
ience and predictors of electrical storm in patients with
implantable cardioverter-defibrillator. Am J Cardiol.
2006;97:389-392.
62. Credner SC, Klingenheben T, Mauss O, Sticher-
ling C, Hohnloser SH. Electrical storm in patients with
transvenous implantable cardioverter-defibrillators: in-
cidence, management and prognostic implications.
63. Kudenchuk PJ, Cobb LA, Copass MK, et al. Amio-
darone for resuscitation after out-of-hospital cardiac
1999;341:871-878.
64. Nademanee K, Taylor R, Bailey WE, Rieders DE,
Kosar EM. Treating electrical storm: sympathetic block-
ade versus advanced cardiac life support-guided
65. Dijkman B, den Dulk K, Wellens HJ. Manage-
ment of electrical instability after ICD implantation.
66. Burjorjee JE, Milne B. Propofol for electrical storm;
a case report of cardioversion and suppression of ven-
2002;49:973-977.
67. Tanabe Y, Chikushi M, Washizuka T, et al. Sup-
pression of electrical storm by biventricular pacing in
a patient with idiopathic dilated cardiomyopathy and
ventricular tachycardia. Pacing Clin Electrophysiol.
overdriving pacing as an adjunct to antiarrhythmic drug
therapy for electrical storm in acute myocardial
69. Bansch D, Oyang F, Antz M, et al. Successful cath-
ereter ablation of electrical storm after myocardial
70. Schreick J, Zrenner B, Deisenhofer I, Schmitt C.
Rescue ablation of electrical storm in patients with is-
chemic cardiomyopathy: a potential-guided ablation
approach by modifying substrate of intractable, un-
mappable ventricular tachycardias. Heart Rhythm.
71. Quilf TE, Barold SS, Sussman BL. Discontinuing
an implantable cardioverter defibrillator as a life-
72. Sears SF Jr, Conti JB. Quality of life and psycho-
logical functioning of ICD patients. Heart. 2002;87:488-
493.

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