Implantable cardioverter-defibrillator (ICD) therapy is proven to reduce mortality. However, ICD shocks are painful and cause acute adverse physiological effects. The mortality benefit comes at the cost of some morbidity, including the pain and adverse effects caused by defibrillating shocks, both appropriate and inappropriate. Although antitachycardia therapy (ATP) may be proarrhythmic, it has many advantages over shocks. Shocks reduce the quality of life and cause myocardial injury, but ATP does not. Frequent delivered or aborted shocks deplete the ICD’s battery, but ATP does not. Responses to ATP that does not terminate the tachycardia can be used to differentiate ventricular tachycardia (VT) from sinus or atrial tachycardia with 1:1 atrioventricular (AV) conduction and thus optimize ICD programming.

Most ventricular arrhythmias treated in the ventricular fibrillation (VF) zone are in fact monomorphic VT and can be terminated by ATP. Therefore, many newer ICDs permit 1 second of ATP before or during charging in the VF zone. ATP immediately after detection, whereas shocks are delayed 6–15 s. Overtreatment of self-terminating VT is more common with ATP than with shocks because ATP is delivered for slower VTs. ATP in faster rate zones, and existing supraventricular tachycardia (SVT) discrimination algorithms, the PREPARE study programming can be safely used to reduce the combined morbidity of spontaneous shock episodes, arrhythmic syncope, and untreated sustained symptomatic VT/VF events in primary prevention patients.

In this issue of the Journal, Watanabe et al report the primary result of the SATISFACTION study, which aimed to provide a more precise estimate of the efficacy of ATP therapy in the Japanese ICD population. The authors should be congratulated for the effort they put into the thorough analysis of populations with and without an ischemic etiology. They demonstrate that ATP success was similar for patients in both groups. Although the primary prevention ratio was similar in both studies (48% in PainFREE and 42% in SATISFACTION), non-ischemic etiology was more prevalent in the SATISFACTION (59%) than in the PainFREE (17%) study.

Self-Terminating Tachycardias

Although the narrower term “inappropriate therapy” means delivered therapies during a rhythm other than VT/VF, the broader term “unnecessary therapy” also includes therapies for VT/VF that would have terminated if the therapy had been delayed. Strategically programmed shock therapies reduce any unnecessary therapies. Two prospective randomized trials in primary prevention patients reported fewer shocks using a duration of 30 beats for fast VT/VF (up to 10 s) without a significant increase in syncope or death. It seems likely that the duration of up to 30 beats studied for fast VT is safe and preferable for slower VTs. Overtreatment of self-terminating VT is more common with ATP than with shocks because ATP is delivered immediately after detection, whereas shocks are delayed 6–15 s. Early studies were performed with short detection durations of 12–16 beats, and evidence suggests that many of these VTs would have terminated spontaneously if the duration had been longer, particularly in primary prevention patients. In the PREPARE study, the duration for detection of fast VT was 30/40 beats. The adjusted success rate for ATP was only 49%, and at least 85% of fast VTs lasting at least 12 beats terminated spontaneously. In the RELEVANT study, 90% of fast VTs lasting at least 12 beats terminated spontaneously. In the PainFREE and SATISFA CTY studies the detection in the VF zone was similarly short (18 of 24 intervals). ATP during charging has the same battery cost as a shock and increases the likelihood that shocks will be delivered for self-
with VT/VF or VF only, regardless of etiology. **Figure** shows the strategic ICD programming that I recommend for shock reduction. Primary prevention patients have fewer VT episodes with faster ventricular rates than secondary prevention patients with monomorphic VT.

**Figure.** Strategic ICD programming for shock reduction in (A) primary prevention patients, (B) secondary prevention patients and (C) patients with VF/polymorphic VT only. See the text for details. *The boundary between 2 VT zones should be based on the cycle length at which different durations for detection or different ATP is preferred. **Especially in CPVT, short detection intervals and exceptionally long detection times (delay) are recommended.

ATP, antitachycardia pacing; BrS, Brugada syndrome; bpm, beats per minute; CL, cycle length; CPVT, catecholaminergic polymorphic ventricular tachycardia; cVT, clinically documented ventricular tachycardia; LQT, long QT syndrome; SVT, supraventricular tachycardia; VF, ventricular fibrillation; VT, ventricular tachycardia.

**Programming Detection and Therapies**

Programming to minimize unnecessary therapies is a major focus of managing ICD recipients. Because there is no significant difference in the efficacy of ATP between a ischemic and nonischemic etiology, as the SATISFACTION study demonstrated, the strategic programming of ICDs can be done separately for primary or secondary prevention, and in patients terminating VT because the confirmation process after charging (reconfirmation) is less specific than the usual redetection process after ATP.
yet rarely withholds therapy from hemodynamically significant VTs; (3) systematic programming of SVT-VT discriminators in patients capable of rapid AV conduction; and (4) programming of ATP in all detection zones. For primary prevention, 1- or 2-zone programming is recommended.

In secondary prevention patients with clinical monomorphic VT, the VT interval should be set at least 40 ms longer (200 beats/min slower) than the slowest VT. In the VT zone, therapy is programmed to 2–4 bursts of ATP, followed by maximum output shocks. There is controversy about the output of ICD shocks because higher output shocks might cause severer myocardial injury. However, I prefer programming using maximum output shocks to maximize the likelihood of terminating atrial fibrillation and minimize the risk of inducing VF by shocks weaker than the upper boundary of the defibrillation threshold. The boundary between the 2 VT zones should be based on the cycle length at which different durations for detection or different ATP is preferred. For patients whose only arrhythmia is polymorphic VT/VF (eg, long QT syndrome, Brugada syndrome, catecholaminergic polymorphic VT), single-zone programming with a sinus-VF boundary in the range of 300–240 ms may be considered. Especially in CPVT, short detection intervals and exceptionally long detection times (delay) are recommended. Because electrical storm can be initiated by appropriate or inappropriate shocks and subsequent catecholaminergic release.

Recently, a subanalysis of the MADIT-RIT study demonstrated the importance of ICD reprogramming for mortality reduction. Conventional ICD programming was associated with an increased risk of all-cause mortality as compared with ICD programming with a cut-off >200 beats/min, even when taking into account ICD therapies delivered. Tailored ICD programming is sometimes difficult, but should be done.

Disclosures

Akihiko Nogami has received honoraria from St. Jude Medical and Boston Scientific; and an endowment from Medtronic and Johnson & Johnson.

References

1. The Antiarrhythmics versus Implantable Defibrillators (AVID) Investigators. A comparison of antiarrhythmic drug therapy with implantable defibrillator in patients with continuing ventricular arrhythmias. N Engl J Med 1997; 337: 1576–1583.
2. Moss AJ, Zareba W, Hall WJ. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. N Engl J Med 2002; 346: 877–883.
3. Bardy GH, Lee KL, Mark DB, Poole JE, Packer DL, Boineau R, et al; Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT) Investigators. Amiodarone or an implantable cardioverter-defibrillator for congestive heart failure. N Engl J Med 2005; 352: 225–237.
4. Murakoshi N, Aounuma K. Epidemiology of arrhythmias and sudden cardiac death in Asia. Circ J 2013; 77: 2419–2431.
5. Sweeney MO, Sherefese L, DeGroot PJ, Wathen MS, Wilkoff BL. Differences in effects of electrical therapy type for ventricular arrhythmias on mortality in implantable cardioverter-defibrillator patients. Heart Rhythm 2010; 7: 353–360.
6. Tereshchenko LG, Faddis MN, Fetics BJ, Zelik KE, Efimov IR, Berger RD. Transient local injury current in right ventricular electrogram after implantable cardioverter-defibrillator shock predicts heart failure progression. J Am Coll Cardiol 2009; 54: 822–828.
7. Swerdlov C, Gillberg J, Khairy P. Sensing and detection. In: Ellenbogen K, Kay G, Lau C, et al, editors. Clinical cardiac pacing, defibrillation and resynchronization therapy, 4th edn. WB Saunders, Philadelphia, 2011; 56–126.
8. Wathen MS, DeGroot PJ, Sweeney MO, Stark AJ, Otterness MF, Adkisson WO, et al. Prospective randomized multidcenter trial of empirical anti-tachycardia pacing versus shocks for spontaneous rapid ventricular tachycardia in patients with implantable cardioverter-defibrillators: Pacing Fast Ventricular Tachycardia Reduces Shock Therapies (PainFREE Rx II) trial results. Circulation 2004; 110: 2591–2596.
9. Wilkoff BL, Ousdigian KT, Sterns LD, Wang ZJ, Wilson RD, Morgan JM; EMPRIC Trial Investigators. A comparison of EMPric to Physician-tailored program:ting of Implantable Cardioverter-defi-brillator: Results from the prospective randomized multidcenter EMPRIC trial. J Am Coll Cardiol 2006; 48: 330–339.
10. Wilkoff BL, Williamson BD, Stern RS, Moore SL, Lu F, Lee SW, et al. Strategic programming of detection and therapy parameters in implantable cardioverter-defibrillators reduces shocks in primary prevention patients: Results from the PREPARE (Primary Prevention Parameters Evaluation) study. J Am Coll Cardiol 2008; 52: 541–550.
11. Watanabe T, Inoue K, Kashihase K, Mine T, Hirooka K, Shutta R, et al; on behalf of the SATISFACTION Investigators. Efficacy of anti-tachycardia pacing for terminating fast ventricular tachycardia in Japanese implantable cardioverter defibrillator patients: Primary results of the SATISFACTION Study. Circ J 2014; 78: 2643–2650.
12. Ruwald AC, Schuger C, Moss AJ, Kutyifa V, Ofshansky B, Greenberg H, et al. Mortality reduction in relation to ICD programming in MADIT-RIT. Circ Arrhythm Electrophysiol 2014 August 18, doi:10.1161/CIRCEP.114.001623.
13. Gasparini M, Menozzi C, Proclemer A, Landolina M, Iacopino S, Carboni A, et al. A simplified biventricular defibrillator with fixed long detection intervals reduces implantable cardioverter defibrillator (ICD) interventions and heart failure hospitalizations in patients with non-ischaemic cardiomyopathy implanted for primary prevention: The RELEVANT: Role of long detection window programming in patients with LEFT Ventricular Ar dysfunction, Non-ischemic eTiology in primary prevention treated with a biventricular ICD study. Eur J Heart J 2009; 30: 2758–2767.
14. Wilkoff BL, Hess M, Young J, Abraham WT. Differences in tachyarrhythmia detection and implantable cardioverter defibrillator therapy by primary or secondary prevention indication in cardiac resynchronization therapy patients. J Cardiovasc Electrophysiol 2004; 15: 1002–1009.