JACC Vol. 21, No. 4
March 15, 1993:895–900

Importance of Abortive Shock Capability With Electrogram Storage in Cardioverter-Defibrillator Devices

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Objectives. This study evaluates the ability of a third-generation cardioverter-defibrillator to abort energy delivery and the importance of electrogram storage in analyzing the aborted events.

Background. In the Cadence Tiered Therapy Defibrillator, when a tachycardia satisfies detection criteria for cardioversion or defibrillation therapy, high voltage capacitors begin charging. The Cadence defibrillator continues monitoring the rhythm during charging and if the rate decreases to below the rate triggering therapy, charging is terminated. This event is registered as an aborted shock. The defibrillator also has the ability to store intracardiac electrogram recordings of the electrical events that precipitate device therapy or aborted shocks.

Methods. During a mean follow-up interval of 10 ± 7 months, 55 aborted events were registered by the Cadence defibrillator in 19 of the 49 patients who received it. Thirty-two stored ventricular electrograms of events leading to aborted shocks were available for analysis in 15 patients.

Results. Intracardiac electrogram recordings demonstrated the probable electrical events leading to these aborted shocks included nonsustained ventricular tachycardia (n = 10), nonsustained rapid polymorphic ventricular tachycardia/ventricular fibrillation (n = 2), atrial fibrillation (n = 5), supraventricular tachycardia (n = 2) and electrical noise (n = 13). Eleven patients had a therapeutic intervention initiated as a consequence of the diagnostic information provided by analysis of intracardiac electrogram recordings. Four of the 15 patients had no changes made. During a follow-up period of 9 ± 5 months after therapy was altered, no patient had subsequent aborted shocks. Five patients have had seven appropriate shocks for sustained ventricular tachycardias.

Conclusions. The ability of Cadence defibrillator to continue tachycardia sensing during capacitor charging and to abort shock therapy for self-terminating events prevented unnecessary shocks in 18 (37%) of the 49 patients. Intracardiac electrogram recordings were critical for instituting appropriate therapy that may have prevented unnecessary device charging and inappropriate discharges.

(J Am Coll Cardiol 1993;21:895–900)

Despite the documented safety and efficacy of implantable cardioverter-defibrillator therapy, most devices are committed to deliver a shock once detection criteria are satisfied and the device begins charging. Termination of ventricular tachycardia during capacitor charging can result in a shock delivered during sinus rhythm. Third-generation implantable cardioverter-defibrillator devices offer several advances in device therapy, including the use of antitachycardia pacing with cardioversion and defibrillation shock capabilities (1–4). To avoid unnecessary implantable cardioverter-defibrillator shocks for self-terminating arrhythmias, the third-generation Cadence Tiered Therapy Defibrillator System continues to monitor the rhythm during device charging to determine if the arrhythmia persists. If a rate less than the rate triggering therapy is detected, charging is terminated immediately and no therapy is delivered. This type of electrical event is registered as an aborted shock in the Cadence system. Aborted therapy can occur only when the device has charged to deliver a shock, not when antitachycardia pacing therapy is initiated. The purpose of our study was 1) to determine the frequency of aborted shocks during follow-up; 2) to evaluate the electrical events that precipitated the aborted shock; and 3) to determine if recognition of the electrical events could result in interventions designed to prevent subsequent electrical events leading to aborted shocks.

Methods

Study group. The study group consisted of 49 patients who received a Ventritex Cadence Tiered Therapy Defibrillator System between August 1989 and September 1991 at the Hospital of the University of Pennsylvania. There were

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Manuscript received April 20, 1992; revised manuscript received August 31, 1992, accepted September 1, 1992.

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0735-1097/93/$6.00

Table 1. Cardiac Diagnosis at Admission

Cardiac Diagnosis	No. of Patients
Coronary artery disease	33
Dilated cardiomyopathy	12
Rheumatic heart disease	2
Long QT syndrome	1
Mitral valve prolapse + regurgitation	1

40 men and 9 women with a mean age of 63 ± 9 years (range 39 to 78). Left ventricular ejection fraction ranged from 14% to 72% (mean 30 ± 12%). The majority of patients had coronary artery disease (Table 1). The diagnosis of the arrhythmia at the time of admission is listed in Table 2. Patients received a cardioverter-defibrillator device for therapy of life-threatening ventricular arrhythmias after electrophysiologic study–guided antiarrhythmic drug therapy failed or if they presented with a cardiac arrest and had no inducible arrhythmias during baseline electrophysiologic testing. Patients were followed up for a mean of 10 ± 7 months (range 1 to 23) after device implantation.

Cadence Tiered Therapy Defibrillator implantation and testing. A discussion of the general procedure for the implantation of cardioverter-defibrillators at the Hospital of the University of Pennsylvania has been described in detail elsewhere (5). In the operating room, either a right ventricular apical transvenous bipolar endocardial screw-in pacing lead (n = 16) or a left ventricular epicardial screw-in pacing lead (n = 33) was implanted. Pacing and sensing thresholds were obtained and, when necessary, the leads were repositioned to obtain satisfactory thresholds. Satisfactory sensing thresholds were defined as an R wave amplitude recorded during the patient's baseline supraventricular rhythm of >5 mV and pacing thresholds <1.5 V at 0.5 ms pulse width. Defibrillation patches were placed by lateral thoracotomy, typically with an anterior patch positioned over the intraventricular septum and a posterior patch positioned over the posterolateral left ventricular free wall. Defibrillation thresholds were obtained with an external defibrillator (Ventritex HVS-02). When necessary, the patches were repositioned to obtain optimal defibrillation thresholds.

The Cadence Tiered Therapy Defibrillator System can be configured to treat ventricular fibrillation alone (a defibrillator only) or to treat both ventricular tachycardia and ventricular fibrillation (an antitachycardia pacemaker–cardioverter and a defibrillator). The device is routinely programmed to deliver a shock for an event that satisfies the programmed rate criteria for ventricular fibrillation detection that is approximately 10 J above the defibrillation threshold. Before hospital discharge, ventricular fibrillation and, when appropriate, ventricular tachycardia were induced to confirm the efficacy of device defibrillation and antitachycardia pacing algorithms. Six to 8 weeks after discharge, the patient returned to the Hospital of the University of Pennsylvania. Arrhythmias were again induced and therapy algorithms were confirmed or modified.

Table 2. Arrhythmia Diagnosis at Admission

Cardiac Rhythm	Patients (no.)
Cardiac arrest	20
Sustained ventricular tachycardia	20
Syncope	8
Nonsustained ventricular tachycardia	1

Electrogram storage capabilities and follow-up. The Ventritex Cadence Tiered Therapy Defibrillator System can also store intracardiac electrogram recordings of electrical events that lead to device therapy (6). The recordings are obtained by an epicardial or endocardial bipolar rate sensing lead system and are filtered with a bandpass centered at 30 Hz. The device has programmable storage capacities for either one 64-s event, three 32-s events or seven 16-s events. The storage capabilities are triggered by either device therapy or redetection of a rate less than the programmed ventricular tachycardia cutoff rate. The nominal setting for electrogram storage is for three 32-s events with storage triggered by detection of a rate less than ventricular tachycardia cutoff rate. The majority of the devices in our patients had nominal electrogram storage settings. During device implantation and at the time of electrophysiologic evaluation before discharge and at 6 weeks, real time bipolar electrogram recordings of sinus rhythm and all induced arrhythmias were obtained.

The Ventritex Cadence Tiered Therapy Defibrillator System stores the number of defibrillations, cardioversions and antitachycardia pacing attempts made and the number of aborted shocks for every electrical event it senses that satisfies criteria for shock therapy. It also records intracardiac electrograms for every electrical event it senses that satisfies criteria for device therapy, but only the very last three electrical events can be retrieved for electrographic analysis because of the limits of its storage capacities. Thus, if a patient has more than three electrical events that initiated device therapy, intracardiac electrograms from only the last three events will be available for evaluation; the other electrical events will be noted by the therapy they initiated (that is, defibrillation for an electrical event that satisfied the rate criteria for ventricular fibrillation detection, antitachycardia pacing for an electrical event that satisfied the rate criteria for ventricular tachycardia detection).

Clinical evaluation and device interrogation were performed every 2 months, or as soon as possible after a symptomatic arrhythmia episode. During this evaluation, the device was interrogated to determine therapy history and to recover any stored intracardiac electrograms. Recordings of real time electrograms of sinus rhythm are obtained, as well as stored electrogram recordings from device termination of any episode of spontaneous ventricular fibrillation or ventricular tachycardia, or both, during the evaluation.

Table 3. Characterization of Events Preceding Aborted Shocks: Analysis of Stored Electrograms

Rhythm	Electrogram Same as SR Electrogram	ΔRR (60 ms)
Nonsustained unimorphic VT*	No	—
Nonsustained polymorphic VT/VF†	No (continuously changing morphology)	Yes
Atrial fibrillation*	Yes	Yes
Supraventricular tachycardia*	Yes	No
Lead fracture	Electrical noise	Electrical noise

*Cycle length >260 ms. †Cycle length <260 ms. ΔRR = change in RR interval; SR = sinus rhythm; VT = ventricular tachycardia; VT/VF = ventricular tachycardia or ventricular fibrillation.

Criteria for rhythm classification and data analysis. Electrical events were separated into five categories: nonsustained uniform ventricular tachycardia, rapid nonsustained polymorphic ventricular tachycardia/ventricular fibrillation, atrial fibrillation, regular supraventricular tachycardia or electrical noise according to the criteria listed in Table 3.

The criteria listed in Table 3 are based on the finding (6,7) that ventricular tachycardia has been associated with a change in local bipolar electrogram morphology 93% of documented episodes at ventricular tachycardia induced in the electrophysiology laboratory or operating room. The limitations associated with these criteria are that 1) 7% of episodes of ventricular tachycardia have the same local electrogram morphology as that of supraventricular rhythm, and 2) a change in local electrogram morphology may occur with bundle branch block aberration ipsilateral to the recording leads during supraventricular tachycardia (7,8). Variability in the RR interval was not used as part of the criteria for diagnosing nonsustained ventricular tachycardia. Spontaneous changes in RR intervals in unimorphic ventricular tachycardia may vary by as much as 100 ms at the onset of tachycardia (9). To determine the events leading to the aborted shocks, three observers who had no knowledge of the data reviewed the retrieved intracardiac electrograms.

Data are expressed as mean values ± SD.

Results

Incidence of aborted shocks. During follow-up, 27 patients had 406 episodes interpreted by the Ventritex Cadence Tiered Therapy Defibrillator System as ventricular tachycardia or ventricular fibrillation. One hundred thirty-five of these episodes led to initial cardioverter-defibrillator shock, and 216 led to antitachycardia pacing. The remaining 55 episodes led to aborted shocks, which occurred in 18 patients and will be the focus of the rest of this report. The time from device implantation to aborted event was 6 ± 4 months (range 1 to 14).

Table 4. Electrical Events Leading to Aborted Shocks

Arrhythmia	Patients (no.)	Events (no.)
Nonsustained unimorphic VT only	4	7
SVT only	2	2
Atrial fibrillation only	1	3
Nonsustained polymorphic VT/VF	1	2
Nonsustained unimorphic VT + atrial fibrillation	1	3/2
Lead fracture (adapter disruption in 5 patients)	6	13

SVT = supraventricular tachycardia; other abbreviations as in Table 3.

Twenty-three of the 55 aborted shock events in the 18 patients were not available for electrogram analysis because of subsequent arrhythmic events. The remaining 32 events available for electrogram analysis occurred in 15 patients; in the other three patients, electrogram recordings of the aborted shocks were not available because the electrograms were replaced by other electrical events.

Of the 18 patients with aborted events, 3 had endocardial and 15 had epicardial sensing leads. The patients' ages ranged from 51 to 71 years (mean 64 ± 8) and the ejection fraction ranged from 18% to 72% (mean 32 ± 14%).

Electrical events leading to aborted shocks. The three observers, who had no knowledge of patient data, uniformly agreed on the classification of the electrogram recordings of the event leading to the aborted shock in 26 (81%) of the 32 episodes. Two of the three reviewers agreed on 6 (19%) of the episodes, and on a second, unblinded review, a consensus was obtained for rhythm classification by all three reviewers. Of the 32 events leading to an aborted event, 10 were classified as nonsustained uniform ventricular tachycardia, 2 as supraventricular tachycardia, 5 as atrial fibrillation, 2 as nonsustained polymorphic ventricular tachycardia/ventricular fibrillation and 13 as consistent with transient lead interruption (Table 4). Examples of these events are shown in Figures 1 to 4.

Alteration in treatment secondary to recognition of the electrical events leading to aborted shock. Of the 15 patients with recorded aborted shocks, 11 had their device reprogrammed, antiarrhythmic agents added or lead adapter changed as a result of the information obtained from analysis of the stored intracardiac electrograms associated with the aborted shock (Table 5). The device was reprogrammed in only 4 of the 11 patients; antiarrhythmic drug therapy was initiated in 1 patient, the device was reprogrammed and antiarrhythmic drug therapy initiated in 1 and a fractured lead adapter (Daig LA211) was replaced in 5 (Table 5).

Follow-up after recognition of events leading to aborted shocks. During a follow-up period of 9 ± 5 months (range 2 to 19) after changes were made, no patient had further aborted shocks; however, 6 of the 18 patients did have 25 events leading to device therapy. Five patients had seven shocks delivered for sustained ventricular tachycardia confirmed by analysis of stored intracardiac electrograms. Seventeen of the 25 episodes were sustained ventricular tachy-

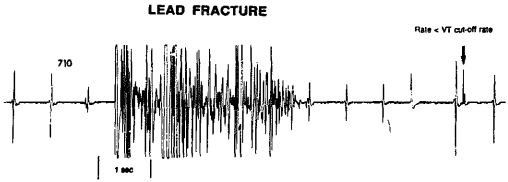


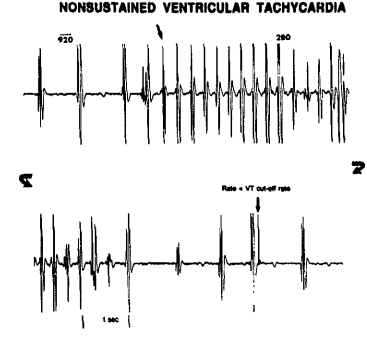
Figure 1. Electrical artifact consistent with disruption of the rate-sensing lead system. The 1-s marker is located at the **bottom left** of the figure. The marker at right **(arrow)** signifies that the device has sensed a rate that is less than the ventricular tachycardia (VT) cutoff rate. Supraventricular rhythm at a cycle length of 710 ms is seen both before and up to and after this marker. The rapid high frequency spikes that bear no resemblance to the morphology of the electrograms recorded during supraventricular rhythm are electrical artifact.

cardia and were treated successfully with antitachycardia pacing. One patient had a single episode of paroxysmal atrial fibrillation precipitating inappropriate antitachycardia pacing.

Discussion

Implantable cardioverter-defibrillators have been widely accepted as life-saving therapy for many patients with serious ventricular arrhythmias (10–12). Many studies have evaluated the number of device discharges after device implantation. An inability in the past to precisely determine the cause of the device discharges has limited the adequate evaluation of patient outcome (10). This inability also has limited potentially helpful alterations in therapy, especially when the device reacts to a rapid nonlife-threatening arrhythmia. The Ventritex Cadence Tiered Therapy Defibrillator System can store recorded intracardiac electrograms from one, three or seven events, depending on device programming, that trigger device therapy (including device charging).

Figure 2. Example of nonsustained uniform ventricular tachycardia (VT). The 1-s marker is located at the **lower left**. The morphology of the electrogram at the beginning of the tracing matched that of the real time electrograms obtained during normal sinus rhythm recorded at the time of device implantation. The mean cycle length before the tachycardia episode equals 920 ms. The tachycardia begins suddenly, reaches the tachycardia cutoff rate **(slanted arrow)** and continues at a cycle length of 280 ms before converting to a supraventricular rhythm. The morphology of the local electrogram during tachycardia shows a large downward deflection, a large upward deflection and again a large downward deflection and is clearly different from the morphology of the supraventricular rhythm in which a small downward deflection is followed by a large upward, downward and again upward deflection.



Our study showed that in 37% of patients, continued sensing during defibrillator charging prevented unnecessary shocks that might have occurred in committed devices. The device recognized episodes of nonsustained ventricular tachycardia (n = 10), nonsustained polymorphic ventricular tachycardia/ventricular fibrillation (n = 2), supraventricular tachycardia (n = 2), atrial fibrillation (n = 5) and electrical noise (n = 13) as self-limited episodes not requiring defibrillation therapy.

Several of the third-generation implantable cardioverter-defibrillators (Medtronic PCD 7217B, Intermedics Res-Q, Siemens-Pacesetter Siecure) are committed to deliver a shock once they detect a rapid rate (more rapid than the programmed ventricular fibrillation cutoff rate) regardless of its duration (3). Three devices (CPI PRx, Telectronic Guardian ATP 4210 and Ventritex Cadence) reevaluate the rhythm, after the capacitors are charged but before the device is discharged and have the ability to withhold therapy if the rate has fallen below the ventricular fibrillation cutoff rate (3). Only with the Ventritex Cadence Tiered Therapy Defibrillator System is this undelivered shock recorded and are the data available for retrieval.

Other implantable cardioverter-defibrillators can retrieve the arrhythmias initiating device therapy, but these are in the form of rate counters or RR intervals or include the electrograms from only a few (not 30) seconds during the detected episode. The ability to precisely determine the cause of the aborted shock with the retrieved electrograms allowed us to appropriately intervene with a lead adapter replacement when needed (for electrical noise), device reprogramming or antiarrhythmic agent alterations, or both (for supraventricular tachycardia, nonsustained ventricular tachycardia and atrial fibrillation), or not to change therapy for nonsustained polymorphic ventricular tachycardia/ventricular fibrillation.

The electrical noise that was recorded and that initiated

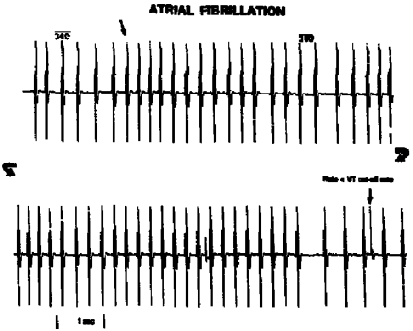
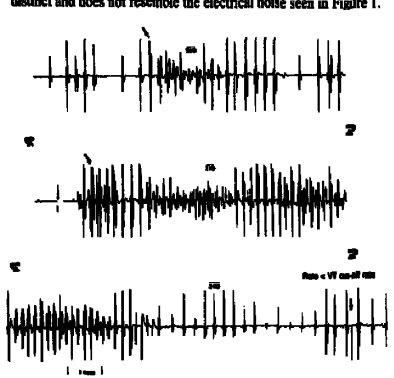


Figure 3. Atrial fibrillation. The 1-s marker is located at the bottom left of the figure. There is no change in the electrogram morphology throughout this figure, either at the very beginning when the mean cycle length is 340 ms, once the rate has increased and satisfied the ventricular tachycardia (VT) cutoff rate (slanted arrow) when the mean cycle length is 280 ms or after the rate has slowed to less than the tachycardia cutoff rate. The morphology of these electrograms matched the morphology of the real time electrograms obtained during the patient's return visit when he had atrial fibrillation with a controlled ventricular response. The irregular RR intervals seen in the recording are also consistent with atrial fibrillation.

an aborted event identified patients who had intermittent lead disruption. This was secondary to problems that occurred with the Daig adapter placed between the epicardial sensing leads and the device itself. The header of the Ventritex Cadence device will accept only in-line bipolar leads and needs an adapter to connect to the epicardial sensing leads. No patient has died as a result of the adapter breaks, but patients have used their defibrillator to treat sustained ventricular tachycardia after the adapter was replaced. Had the many episodes of noise been sensed and recorded as ventricular fibrillation by RR interval counters, appropriate intervention to replace the disrupted adapter would undoubtedly have been delayed, with potentially disastrous consequences. Because adapters are only necessary when epicardial sensing leads are used, we now use only endocardial sensing leads with the Ventritex Cadence Tiered Therapy Defibrillator System, essentially eliminating this source for aborted shocks.

Figure 4. Nonsustained polymorphic ventricular tachycardia (VT)/ventricular fibrillation. The 1-s marker is located at the bottom left of the figure. The initial cycle length is variable, and after a long-short interval, a change in morphology occurs, as well as a transient increase in the mean cycle length to 260 ms (which satisfies the tachycardia cutoff rate [angled arrow]). This sequence is repeated in the middle panel, where a long-short interval initiates a change in morphology and an increase in the mean cycle length to 210 ms, again satisfying the tachycardia rate detection criteria (slanted arrow in the second panel). The mean cycle length subsequently slows to 340 ms and falls to less than the tachycardia cutoff rate. The morphology of the tachycardia, although irregular and rapid, is distinct and does not resemble the electrical noise seen in Figure 1.



The ability to differentiate atrial fibrillation from nonsustained ventricular tachycardia can also be helpful in programming the device for optimal function. The presence of atrial fibrillation can usually be determined by using RR interval counters and intracardiac electrogram recordings because of its irregular rate (13). However, because nonsustained ventricular tachycardia can also be very irregular, it is helpful to have an electrogram morphology during the arrhythmia that matches real time recordings during sinus rhythm when atrial fibrillation is diagnosed. Whatever the cause of the aborted shock, recognition of the electrical events appears to allow an intervention that prevents subsequent unnecessary charging of the implantable cardioverter-defibrillator. A decrease in the number of times the device charges can potentially increase battery life and longevity of the unit.

Limitations of the study. Although the combination of abortive shock capability and electrogram storage of the electrical events leading to the aborted shock therapy is helpful, there are limitations to its usefulness. There are

Table 5. Alterations in Treatment for Recognition of Electrical Events Leading to Aborted Shocks

Event Leading to Aborted Shock	Device Sensing Criteria Altered	Antiarrhythmic Agents Added	Device Therapy Altered + Antiarrhythmic Agents Added	Adapter Breaks Requiring Surgical Replacement	No Changes
Lead adapter fracture				5	1*
Nonsustained unimorphic VT	2 (VT cutoff rate changed from 180 to 360 ms and VF cutoff rate changed from 290 to 270 in 1; 330 to 300 ms in 1)	1 (mexiletine added)			1
SVT			1 (cutoff rate changed from 430 to 400 ms and quinidine added)		1
Atrial fibrillation	1 (cutoff rate changed from 350 to 315 ms)				
Nonsustained polymorphic VT/VF					1
Nonsustained unimorphic VT + atrial fibrillation	1 (VT zone was programmed on with cutoff rate of 350 ms)				

*Patient died of nonarrhythmic causes before the lead adapter was changed. All values are expressed as number of patients. Abbreviations as in Tables 3 and 4.

patients in whom the electrogram morphology is similar during sinus rhythm and ventricular tachycardia (7). As noted, approximately 7% of episodes of ventricular tachycardia have the same electrogram morphology as that of supraventricular rhythm and a change in local electrogram morphology may occur with bundle branch aberration during supraventricular tachycardia (8). This would limit the ability to differentiate adequately supraventricular tachycardia–atrial fibrillation from ventricular tachycardia. The availability of electrogram recordings from wide bipolar electrode pairs may provide supplemental information that may improve the diagnostic capability of electrogram storage information. Finally, although no aborted shocks occurred during the follow-up period of 9 ± 5 months after therapy or device programming was changed, this period may not be long enough to know whether these alterations (Table 5) had a clinically significant effect.

Conclusions. We showed that 18 (37%) of 49 patients with the Ventritex Cadence Tiered Therapy Defibrillator System had aborted shocks during a follow-up period of 10 ± 7 months. The most common arrhythmia resulting in an aborted shock was nonsustained ventricular tachycardia. The system's ability to record aborted shocks was extremely helpful in allowing us to improve our patients' therapy and to limit unnecessary charging of the device. This was particularly true for those patients who had short-lived electrical noise that triggered an aborted shock. Diagnosis of potential lead disruption allowed immediate surgical replacement of the lead adapter. Thus, the combination of abortive shock capability with electrogram storage of the electrical events leading to the aborted therapy is an important advance in implantable cardioverter-defibrillator therapy.

References

1. Leitch JW, Gillis AM, Wyse G, et al. Reduction in defibrillator shocks with an implantable device combining antitachycardia pacing and shock therapy. J Am Coll Cardiol 1991;18:145–51.
2. Epstein AE, Kay GN, Plumb VJ, Shepard RB, Kirklin JK. Combined automatic implantable cardioverter-defibrillator and pacemaker systems: implantation techniques and follow-up. J Am Coll Cardiol 1989;13:121–31.
3. Klein LS, Miles WM, Zipes DP. Antitachycardia devices: realities and promises. J Am Coll Cardiol 1991;18:1349–62.
4. Sakseng S, Mehta D, Krol RB, et al. Experience with a third-generation implantable cardioverter-defibrillator. J Am Coll Cardiol 1991;67:1375–84.
5. Marchlinski FE, Flores BT, Buxton AE, et al. The automatic implantable cardioverter-defibrillator: efficacy, complications, and device failures. Ann Intern Med 1986;104:481–8.
6. Hook BG, Marchlinski FE. Value of ventricular electrogram recordings in the diagnosis of arrhythmias precipitating electrical device shock therapy. J Am Coll Cardiol 1991;17:985–90.
7. Callans DJ, Hook BG, Marchlinski FE. Use of bipolar recordings from patch-patch and rate sensing leads to distinguish ventricular tachycardia from supraventricular rhythms in patients with implantable cardioverter defibrillators. PACE 1991;14:1917–22.
8. Sarter BH, Hook BG, Callans DJ, Marchlinski FE. Effect of bundle branch block on local electrogram morphology: potential cause of arrhythmia misdiagnosis (abstr). PACE 1992;15:4:562.
9. Volosin KJ, Beauregard LM, Pabiszewski R, Mattingly H, Waxman HL. Spontaneous changes in ventricular tachycardia cycle length. J Am Coll Cardiol 1991;17:409–14.
10. Echt DS, Armstrong K, Schmidt P, Oyer PE, Stinson EB, Winkle RA. Clinical experience, complications and survival in 70 patients with the automatic implantable cardioverter/defibrillator. Circulation 1985;2:289–96.
11. Maloney J, Masterson M, Khoury D, et al. Clinical performance of the implantable cardioverter defibrillator: electrocardiographic documentation of 101 spontaneous discharges. PACE 1991;14:280–5.
12. Winkle RA. The implantable defibrillator: progression from first- to third-generation devices. In: Zipes DP, Jalife J, eds. Cardiac Electrophysiology: From Cell to Bedside. Philadelphia: Saunders, 1990:963–9.
13. Wang PJ, Mandalakas N, Clyne C, et al. Accuracy of rhythm classification using a data log system in implantable cardioverter defibrillators. PACE 1991;14:1911–6.