JACC Vol. 24, No. 6
November 15, 1994:1523–8

Risk Stratification for Arrhythmic Events in Patients With Nonischemic Dilated Cardiomyopathy and Nonsustained Ventricular Tachycardia: Role of Programmed Ventricular Stimulation and the Signal-Averaged Electrocardiogram

GIOIA TURITTO, MD, RATAN K. AHUJA, MD, EDWARD B. CAREF, MA, NABIL EL-SHERIF, MD, FACC

Brooklyn, New York

Objectives. **This study investigated prediction of arrhythmic events by the signal-averaged electrocardiogram (ECG) and programmed stimulation in patients with nonischemic dilated cardiomyopathy.**

Background. **Risk stratification in patients with nonischemic dilated cardiomyopathy remains controversial.**

Methods. **Eighty patients with nonischemic dilated cardiomyopathy and spontaneous nonsustained ventricular tachycardia underwent signal-averaged electrocardiography (both time-domain and spectral turbulence analysis) and programmed stimulation. All patients were followed up for a mean of 22 ± 26 months.**

Results. **Sustained monomorphic ventricular tachycardia was induced in 10 patients (13%), who all received amiodarone. The remaining 70 patients were followed up without antiarrhythmic therapy. Of the 80 patients, 15% had abnormal findings on the time-domain signal-averaged ECG, and 39% had abnormal findings on spectral turbulence analysis. Time-domain signal-averaged electrocardiography had a better predictive accuracy for induced ventricular tachycardia than spectral turbulence analysis (88% vs. 66%, $p < 0.01$). During follow-up, there were 9 arrhythmic events (5 sudden deaths, 4 spontaneous ventricular tachycardia/fibrillation) and 10 nonsudden cardiac deaths. Cox regression analysis showed that no variables predicted arrhythmic events or total cardiac deaths. The 2-year actuarial survival free of arrhythmic events was similar in patients with or without abnormal findings on the signal-averaged ECG or induced ventricular tachycardia.**

Conclusions. **In patients with nonischemic dilated cardiomyopathy, 1) there is a strong correlation between abnormal findings on the time-domain signal-averaged ECG and induced ventricular tachycardia, but both findings are uncommon; and 2) normal findings on the signal-averaged ECG, as well as failure to induce ventricular tachycardia, do not imply a benign outcome.**

(J Am Coll Cardiol 1994;24:1523–8)

Risk stratification for serious arrhythmic events in patients with nonischemic dilated cardiomyopathy remains controversial (1–4). We prospectively performed signal-averaged electrocardiography and programmed ventricular stimulation in 80 patients with nonischemic dilated cardiomyopathy and spontaneous nonsustained ventricular tachycardia. The purpose of this was to identify invasive and noninvasive markers for arrhythmic events during long-term follow-up.

Methods

Patients. Patients were prospectively included in this study if they had 1) nonischemic dilated cardiomyopathy, defined as left ventricular ejection fraction <0.50 without >50% stenosis of any major coronary arteries during cardiac catheterization; 2) no spontaneous sustained ventricular tachycardia/fibrillation or aborted sudden death; 3) frequent ventricular premature complexes (>10/h) and one or more episodes of spontaneous nonsustained ventricular tachycardia defined as three or more ventricular premature complexes, <30 s, at a rate >100/min, during 24-h ambulatory electrocardiography; 4) absence of electrolyte imbalance, antiarrhythmic drug treatment, acute congestive heart failure, cancer or renal failure requiring hemodialysis.

Study design. All patients underwent cardiac catheterization, signal-averaged electrocardiography and programmed ventricular stimulation within 1 month of the index ambulatory electrocardiogram (ECG).

Signal-averaged electrocardiography. Recordings were performed with a commercially available machine (Arrhythmia Research Technology 1200 EPX). For time-domain analysis, signals obtained from three bipolar orthogonal leads were amplified, filtered bidirectionally at frequencies between 25 and 250 Hz and 40 and 250 Hz and combined into a vector magnitude ($\sqrt{X^2 + Y^2 + Z^2}$). High frequency QRS duration,

From the Cardiology Division, Department of Medicine, State University of New York Health Science Center at Brooklyn and Veterans Affairs Medical Center, Brooklyn, New York. This study was presented in part at the 66th Scientific Sessions of the American Heart Association, Atlanta, Georgia, November 1993.

Manuscript received February 9, 1994; revised manuscript received May 12, 1994, accepted June 30, 1994.

Address for correspondence: Dr. Gioia Turitto, State University of New York Health Science Center at Brooklyn, 450 Clarkson Avenue, Box 1199, Brooklyn, New York 11203.

0735-1097/94/$7.00

duration of low amplitude signals <40 μV and root mean square voltage of signals in the last 40 ms of the high frequency QRS interval (RMS40) were calculated at both filter settings. All recordings had a noise level <1 μV at 25 Hz. Findings on the signal-averaged ECG were considered abnormal if 1) RMS40 was <25 μV at 25 Hz and <16 μV at 40 Hz in patients without intraventricular conduction defect (defined as QRS duration >110 ms) (5); and 2) RMS40 was <17 μV at 25 Hz in patients with an intraventricular conduction defect of left bundle branch block type (6). Spectral turbulence analysis was performed as previously reported (7). Four variables were measured for the average of leads X, Y, Z: interslice correlation mean, interslice correlation standard deviation, low slice correlation ratio and spectral entropy. Recordings could be scored between 0 and 4, and an abnormal spectral turbulence analysis result was defined as a score of 3 or 4. Each electrophysiologic study included evaluation of baseline intervals, sinus node and atrioventricular node function (when possible), as well as programmed ventricular stimulation. The stimulation protocol included the delivery of three extrastimuli, twice diastolic threshold, during ventricular pacing at three cycle lengths (600, 500 and 400 ms) to the right ventricular apex and outflow tract. The first extrastimulus (S_2) was placed 40 ms above the ventricular effective refractory period, whereas the second extrastimulus (S_3) was placed so that S_2S_3 interval was equal to S_1S_2. S_3 was then decreased by 10-ms steps until local refractoriness was achieved, at which time S_2 was also shortened, and the sequence was repeated until S_2 was refractory. A similar procedure was followed after introduction of the third extrastimulus (S_4). The following definitions were applied: *induced sustained monomorphic ventricular tachycardia* = ventricular tachycardia with uniform QRS configuration and cycle length >200 ms lasting ≥30 s or requiring termination because of hemodynamic compromise; *induced ventricular flutter* = tachycardia with cycle length ≤200 ms; *induced ventricular fibrillation* = polymorphic tachyarrhythmia requiring direct current shock for termination; *no induced sustained ventricular tachyarrhythmias* = completion of the stimulation protocol without induced sustained ventricular tachyarrhythmias.

Follow-up. Antiarrhythmic therapy was prescribed only if sustained monomorphic ventricular tachycardia was induced by programmed stimulation. The efficacy of antiarrhythmic therapy was evaluated with repeat programmed stimulation or ambulatory electrocardiography, or both, and was defined as suppression of induced sustained ventricular tachycardia or suppression of spontaneous nonsustained ventricular tachycardia and ≥85% reduction of the number of ventricular premature complexes (8). All patients had follow-up contact by clinic visits. Information relative to arrhythmic events and deaths during follow-up was obtained from hospital records or relatives. Sustained ventricular tachycardia was defined as symptomatic ventricular tachycardia requiring intervention for termination. Sudden cardiac death was defined as witnessed death within 1 h of the onset of new symptoms, unwitnessed death within 1 h after the patient was seen alive or unexpected death during sleep (9); nonsudden death included deaths secondary to worsening congestive heart failure. Categorization of deaths was made by one of the investigators who was unaware of the results of the screening tests.

Statistical analysis. Continuous variables are expressed as mean value ± SD unless otherwise stated. Both continuous variables (age, left ventricular ejection fraction, surface QRS duration, number of ventricular premature complexes/hour, number, maximal duration and mean cycle length of runs of nonsustained ventricular tachycardia during 24-h ambulatory electrocardiography, values for signal-averaged ECG variables at 25- and 40-Hz filter settings, HV interval, cycle length of induced sustained monomorphic ventricular tachycardia), as well as categoric variables (gender; history of syncope/presyncope; left ventricular ejection fraction <30%; presence of intraventricular conduction defect; abnormal findings on the time-domain signal-averaged ECG; abnormal spectral turbulence analysis results; induced sustained monomorphic ventricular tachycardia; therapy with amiodarone, digoxin, angiotensin-converting enzyme inhibitors) were analyzed using a Cox regression model to determine factors that covaried with survival (10). This analysis was performed initially using arrhythmic events (spontaneous sustained ventricular tachycardia or fibrillation, sudden death) as an end point and was repeated using total cardiac deaths as an end point. Survival analysis tested differences in the outcome of patients with or without abnormal findings on the signal-averaged ECG (by time-domain criteria or spectral turbulence analysis) or induced sustained monomorphic ventricular tachycardia using the Breslow test (10). Finally, survival analysis based on the results of signal-averaged electrocardiography was performed in the subset of patients with no intraventricular conduction defect.

Results

Patient characteristics. Eighty patients were enrolled in the study (65 men, 15 women; mean [±SD] age of 59 ± 12 years, range 34 to 79). The surface ECG showed sinus rhythm in 75 patients and atrial fibrillation in 5. History of syncope or presyncope was obtained, respectively, in 14 and 6 patients. Surface QRS interval was ≤110 ms in 55 patients and showed an intraventricular conduction defect with left bundle branch block configuration in 25. Mean ejection fraction was 0.27 ± 0.08. Figure 1 illustrates the distribution of left ventricular ejection fraction in the study patients.

Programmed ventricular stimulation and signal-averaged electrocardiography. Programmed stimulation induced sustained monomorphic ventricular tachycardia in 10 patients (13%), ventricular flutter or fibrillation in 7 (9%) and no sustained tachyarrhythmias in 63 (79%). The mean cycle length of induced ventricular tachycardia was 255 ± 10 ms (range 225 to 320). Sustained ventricular tachycardia was induced by two extrastimuli in four patients and by three extrastimuli in the remaining six. Mean HV interval was 54 ± 12 ms, with values >55 ms in 22 (28%) of 80 patients. Abnormal findings on the time-domain signal-averaged ECG

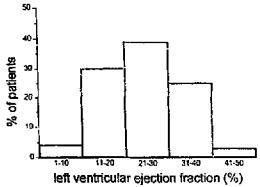

Figure 1. Distribution of left ventricular ejection fraction values in 80 study patients with nonischemic dilated cardiomyopathy.

were detected in 12 patients (15%), whereas spectral turbulence analysis results were abnormal in 31 (39%). The predictive accuracy of time-domain signal-averaged electrocardiography for induced ventricular tachycardia was significantly better than that of spectral turbulence analysis (70 [88%] of 80 vs. 53 [66%] of 80, respectively, $p < 0.01$).

Survival analysis. All study patients were followed up for a mean of 21.8 ± 25.7 months at 6-month intervals, and no patients were lost to follow-up in the interim. In the initial part of the study, patients with inducible ventricular tachycardia were first given class IA antiarrhythmic drugs (procainamide or quinidine); four of these patients underwent repeat programmed stimulation, and they all had persistently induced sustained monomorphic ventricular tachycardia. These four patients were subsequently treated with amiodarone; the remaining patients with inducible tachycardia received amiodarone as the first antiarrhythmic drug. All patients with induced sustained ventricular tachycardia were discharged with amiodarone therapy, which was found to be effective by ambulatory ECG criteria in all patients. Of four patients who underwent repeat programmed stimulation, two had no induced sustained ventricular tachycardia, and two had induced sustained ventricular tachycardia that was slow and hemodynamically tolerated. All patients without induced sustained ventricular tachycardia were discharged without antiarrhythmic drugs. Permanent pacemaker implantation was performed in two patients. One patient had a history of syncope and was found to have an HV interval of 90 ms; permanent pacing was requested by the referring physician. One patient with induced sustained ventricular tachycardia developed severe symptomatic sinus bradycardia and required dual-chamber pacing. No changes in antiarrhythmic therapy were made during follow-up. However, two patients with induced sustained ventricular tachycardia were not compliant with amiodarone therapy. There was a total of nine arrhythmic events (three sustained ventricular tachycardias, one ventricular fibrillation, five sudden deaths) and 10 nonsudden cardiac deaths. Among patients with induced sustained ventricular tachycardia, three had arrhythmic events (ventricular tachycardia in three, two of whom had discontinued amiodarone) and one nonsudden death. Among patients without induced sustained ventricular tachycardia, six had arrhythmic events (sudden death in five, documented ventricular fibrillation in one) and nine nonsudden deaths. There were no arrhythmic events among patients with induced ventricular flutter or fibrillation. Among patients with abnormal findings on the time-domain signal-averaged ECG, two had arrhythmic events and one nonsudden death. Among patients with no abnormal findings on the time-domain signal-averaged ECG, seven had arrhythmic events and nine nonsudden death. Among patients with abnormal spectral turbulence analysis results, five had arrhythmic events and five nonsudden death. Among patients with no abnormal spectral turbulence analysis results, four had arrhythmic events and five nonsudden death.

Survival analysis with the Cox proportional hazards model demonstrated that none of the variables examined was significantly associated with arrhythmic events or total cardiac mortality. Figure 2 shows the survival analysis based on the results of programmed stimulation. Two-year survival free of arrhythmic events was similar in patients with or without induced sustained ventricular tachycardia (75 ± 15% vs. 87 ± 5%, respectively, p = NS). Two-year cumulative survival (without cardiac death) was also similar in patients with or

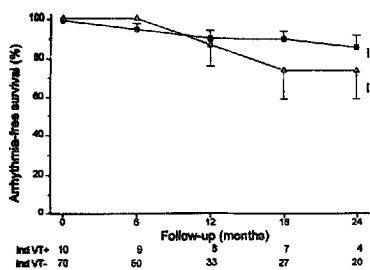

Figure 2. Two-year actuarial survival curves for arrhythmic events in patients with nonischemic dilated cardiomyopathy classified by the outcome of programmed stimulation. The number of patients followed up at each time interval is indicated at the **bottom**. Ind VT+ = induced sustained ventricular tachycardia; Ind VT− = no induced sustained ventricular tachycardia; **triangles** = patients with induced sustained ventricular tachycardia; **squares** = patients with no induced sustained ventricular tachycardia. Data are expressed as mean value ± SE.

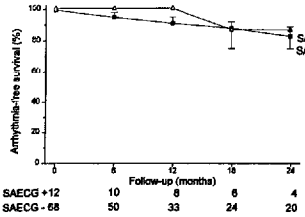

Figure 3. Two-year actuarial survival curves for arrhythmic events in patients with nonischemic dilated cardiomyopathy classified by findings on the time-domain signal-averaged electrocardiogram (SAECG). The number of patients followed up at each time interval is indicated at the **bottom**. SAECG+ = abnormal findings; SAECG− = no abnormal findings; **triangles** = patients with abnormal findings; **squares** = patients without abnormal findings. Data are expressed as mean value ± SE.

without induced sustained ventricular tachycardia (67 ± 16% vs. 71 ± 6%, respectively, p = NS). Figure 3 shows the survival analysis based on the results of the time-domain signal-averaged ECG. Two-year survival free of arrhythmic events was similar in patients with or without abnormal findings on the time-domain signal-averaged ECG (87 ± 12% vs. 83 ± 6%, respectively, p = NS). Two-year cumulative survival was also similar in patients with or without abnormal findings on the time-domain signal-averaged ECG (79 ± 13% vs. 68 ± 7%, p = NS). No significant differences in arrhythmia-free or cumulative survival were found when patients with or without abnormal spectral turbulence were compared. Finally, arrhythmia-free and cumulative survival analysis limited to patients without intraventricular conduction defect did not show any significant differences among patients with or without abnormal findings on the time-domain signal-averaged ECG.

Discussion

This study of a relatively large, homogeneous group of patients with nonischemic dilated cardiomyopathy attempted to identify strategies that could improve risk stratification for serious arrhythmic events. Several noninvasive and invasive variables, including signal-averaged ECG and programmed stimulation results, were examined.

Programmed stimulation and the signal-averaged ECG in nonischemic dilated cardiomyopathy. The induction rate of sustained monomorphic ventricular tachycardia was low in our patients (13%) but similar to that reported in previous studies of patients with nonischemic dilated cardiomyopathy and no spontaneous sustained ventricular tachycardia/ventricular fibrillation/sudden death (0% to 14%) (11–20). Thus, the electrophysiologic substrate for induced sustained monomorphic ventricular tachycardia may be less common in patients with nonischemic dilated cardiomyopathy compared with those with ischemic heart disease (17,21–24). The prevalence of abnormal findings on the time-domain signal-averaged ECG was also low (16%). In patients with nonischemic dilated cardiomyopathy, abnormal findings on the signal-averaged ECG are an accurate predictor for induced sustained monomorphic ventricular tachycardia, whereas abnormal spectral turbulence analysis results do not improve ventricular tachycardia prediction (21–23).

Risk stratification for sudden death in patients with nonischemic dilated cardiomyopathy. An important finding in this study is that the presence of normal findings on the signal-averaged ECG and lack of inducibility of sustained monomorphic ventricular tachycardia did not portend a favorable prognosis. In fact, there was a high incidence of arrhythmic events and a high total cardiac mortality rate in patients with no induced sustained ventricular tachycardia or normal findings on the signal-averaged ECG. Several reports on the prognostic value of programmed stimulation in patients with dilated cardiomyopathy are characterized by small sample size, short follow-up duration (11–15,18,20), inhomogeneous enrollment criteria with inclusion of patients with spontaneous sustained tachyarrhythmias (14,19) and disparate therapeutic approach, with antiarrhythmic drugs being administered empirically to patients with noninducible ventricular tachycardia (20). Our study shares some limitations of previous studies, including small size, but it has the advantage of reporting follow-up data for a well defined group of patients with noninducible ventricular tachycardia, none of whom received empiric antiarrhythmic therapy.

Few studies have investigated the prognostic value of the signal-averaged ECG in nonischemic dilated cardiomyopathy (25–27). In a study by Mancini et al. (26), the time-domain signal-averaged ECG was found to be a predictor of survival in 114 patients with dilated cardiomyopathy. Freedom from adverse events (ventricular tachycardia, death) was significantly higher in patients with normal findings on the signal-averaged ECG than in those with abnormal findings or bundle branch block. However, the nonhomogeneous nature of the study group (including patients with and without sustained ventricular tachyarrhythmias), the empiric use of antiarrhythmic drugs, which could have influenced both the results of the signal-averaged ECG (28) and clinical outcome, may explain the discrepancies between the report of Mancini et al. and the present study. In a recent study of 62 patients with idiopathic dilated cardiomyopathy, Keeling et al. (27) suggested that spectral analysis rather than the time-domain signal-averaged ECG may be useful to identify patients at risk of sudden death. However, the number of adverse events in the Keeling et al. study was small, and no statistical significance was reached. Our data do not support the findings of Keeling et al. We showed that a high degree of spectral turbulence is a nonspecific characteristic in patients with nonischemic dilated cardiomyopathy (23).

Study limitations and clinical implications. One methodologic problem shared by all studies of patients with dilated cardiomyopathy is the difficulty in classifying unwitnessed

sudden cardiac death as an arrhythmic death. The assumption that a sudden death is likely to be due to a tachyarrhythmia was originally made in studies of survivors of myocardial infarction (9) and may not be applicable to patients with nonischemic dilated cardiomyopathy. Although in postinfarction patients the occurrence of sudden death is commonly associated with the finding of sustained ventricular tachycardia or ventricular fibrillation on ECG recordings (29), in patients with dilated cardiomyopathy bradyarrhythmias or electromechanical dissociation may play a more important role (30). If spontaneous ventricular tachyarrhythmias arising from a fixed anatomic–electrophysiologic substrate only cause a limited proportion of lethal events in dilated cardiomyopathy, the low incidence of abnormal findings on the signal-averaged ECG and induced ventricular tachycardia in this setting, and their inability to predict survival, are not surprising. Analysis of risk factors for sudden death in patients with inducible tachycardia is also limited by the lack of a control group, including patients who were followed up without antiarrhythmic therapy. Thus, no conclusion can be drawn from the present study with regard to survival of patients with inducible tachycardia who received amiodarone. However, these patients represented only a small fraction of the total group. By contrast, we found a high sudden death rate in the larger group with no induced sustained ventricular tachycardia and normal findings on the signal-averaged ECG who had no antiarrhythmic treatment during follow-up. These results show that patients with nonsustained ventricular tachycardia and nonischemic dilated cardiomyopathy clearly differ from those with ischemic heart disease; in fact, in the latter setting noninducibility seems to confer a relatively benign prognosis (20,24,31,32). Our data strongly support the conclusion that novel risk stratification strategies for sudden death should be sought in patients with nonischemic dilated cardiomyopathy.

We are indebted to Matthew J. Avitable, PhD, of the Scientific/Academic Computing Center, State University of New York Health Science Center at Brooklyn, for help with statistical analysis.

References

1. Podrid PJ, Fogel RI, Tordjman Fuchs T. Ventricular arrhythmia in congestive heart failure. Am J Cardiol 1992;69:82G–96G.
2. Tamburro P, Wilber D. Sudden death in idiopathic dilated cardiomyopathy. Am Heart J 1992;124:1035–45.
3. Larsen L, Mandam J, Haffajee CI. Sudden death in idiopathic dilated cardiomyopathy: role of ventricular arrhythmias. PACE 1993;16:1051–9.
4. Pires LA, Huang SKS. Nonsustained ventricular tachycardia: identification and management of high-risk patients. Am Heart J 1993;126:189–200.
5. Caref EB, Turitto G, Ibrahim BB, Henkin R, El-Sherif N. Role of band-pass filters in optimizing the value of the signal-averaged electrocardiogram as a predictor of the results of programmed stimulation. Am J Cardiol 1989;64:16–26.
6. Fontaine JM, Rao R, Henkin R, Suneja R, Ursell SN, El-Sherif N. Study of the influence of left bundle branch block on the signal-averaged electrocardiogram: a qualitative and quantitative analysis. Am Heart J 1991;121:494–508.
7. Kelen GJ, Henkin R, Starr A-M, Caref EB, Bloomfield D, El-Sherif N. Spectral turbulence analysis of the signal-averaged electrocardiogram and its predictive accuracy for inducible sustained monomorphic ventricular tachycardia. Am J Cardiol 1991;67:965–75.
8. Marchlinski FE, Buxton AE, Flores BT, Doherty JU, Waxman HL, Josephson ME. Value of Holter monitoring in identifying risk for sustained ventricular arrhythmia recurrence on amiodarone. Am J Cardiol 1985;55:709–12.
9. Greene HL, Richardson DW, Barker AH, and the CAPS Investigators. Classification of deaths after myocardial infarction as arrhythmic or nonarrhythmic (the Cardiac Arrhythmia Pilot Study). Am J Cardiol 1989;63:1–6.
10. BMDP Statistical Software. Berkeley (CA): Univ. of California Press, 1988.
11. Meinertz T, Treese N, Kasper W, et al. Determinants of prognosis in idiopathic dilated cardiomyopathy as determined by programmed electrical stimulation. Am J Cardiol 1985;56:337–41.
12. Paul DS, Marchlinski FE, Buxton AE, Josephson ME. Usefulness of programmed stimulation in idiopathic dilated cardiomyopathy. Am J Cardiol 1986;58:992–7.
13. Das SK, Morady F, DiCarlo L Jr, et al. Prognostic usefulness of programmed ventricular stimulation in idiopathic dilated cardiomyopathy without symptomatic ventricular arrhythmias. Am J Cardiol 1986;58:998–1000.
14. Kron J, Hart M, Schual-Berke S, Niles NR, Hosenpud JD, McAnulty JH. Idiopathic dilated cardiomyopathy: role of programmed electrical stimulation and Holter monitoring in predicting those at risk of sudden death. Chest 1988;93:85–90.
15. Stevenson WG, Stevenson LW, Weiss J, Tillisch JH. Inducible ventricular arrhythmias and sudden death during vasodilator therapy of severe heart failure. Am Heart J 1988;116:1447–54.
16. Fauchier JP, Cosnay P, Mouquet B, Balleh H, Rouesnel P. Late ventricular potentials and spontaneous and induced ventricular arrhythmias in dilated or hypertrophic cardiomyopathies: a prospective study about 83 patients. PACE 1988;11:1974–83.
17. Barnhill SC, Trusty JM, Wood DL, et al. Influence of ventricular function and presence or absence of coronary artery disease on results of electrophysiologic testing for asymptomatic nonsustained ventricular tachycardia. Am J Cardiol 1990;65:722–8.
18. Gossinger HD, Jung M, Wagner L, et al. Prognostic role of inducible ventricular tachycardia in patients with dilated cardiomyopathy and asymptomatic nonsustained ventricular tachycardia. Int J Cardiol 1990;29:215–20.
19. Brembilla-Perot B, Donetti J, Terrier de la Chaise A, Sadoul N, Aliot E, Juilliere Y. Diagnostic value of ventricular stimulation in patients with idiopathic dilated cardiomyopathy. Am Heart J 1991;121:1124–31.
20. Kadish A, Schmaltz S, Calkins H, Morady F. Management of nonsustained ventricular tachycardia guided by electrophysiological testing. PACE 1993;16:1037–50.
21. Turitto G, Fontaine JM, Ursell SN, Caref EB, Henkin R, El-Sherif N. Value of the signal-averaged electrocardiogram as a predictor of the results of programmed stimulation in nonsustained ventricular tachycardia. Am J Cardiol 1988;61:1272–8.
22. Turitto G, Fontaine JM, Ursell S, Caref EB, Bekheit S, El-Sherif N. Risk stratification and management of patients with organic heart disease and nonsustained ventricular tachycardia: role of programmed stimulation, left ventricular ejection fraction, and the signal-averaged electrocardiogram. Am J Med 1990;88:35N–41N.
23. Turitto G, Ahuja RK, Bekheit S, Caref EB, Ibrahim B, El-Sherif N. Incidence and prediction of induced ventricular tachyarrhythmias in dilated cardiomyopathy. Am J Cardiol 1994;73:770–3.
24. Wilber DJ, Olshansky B, Moran JF, Scanlon PJ. Electrophysiological testing and nonsustained ventricular tachycardia: use and limitations in patients with coronary artery disease and impaired ventricular function. Circulation 1990;82:350–8.
25. Middlekauff HR, Stevenson WG, Woo MA, Moser DK, Stevenson LW. Comparison of frequency of late potentials in idiopathic dilated cardiomyopathy and ischemic cardiomyopathy with advanced congestive heart failure and their usefulness in predicting sudden death. Am J Cardiol 1990;66:1113–7.
26. Mancini DM, Wong KR, Simson MB. Prognostic value of an abnormal signal-averaged electrocardiogram in patients with nonischemic congestive cardiomyopathy. Circulation 1993;87:1083–92.
27. Keeling PJ, Kulakowski P, Yi G, Slade AKB, Bent SE, McKenna WJ. Usefulness of signal-averaged electrocardiography in idiopathic dilated cardiomyopathy for identifying patients with ventricular arrhythmias. Am J Cardiol 1993;72:78–84.
28. Steinberg JS, Freedman RA, Bigger JT Jr, and the ESVEM Investigators. Antiarrhythmic drug therapy and the signal-averaged electrocardiogram. In:

El-Sherif N, Turitto G, editors. High Resolution Electrocardiography. Mount Kisco (NY): Futura, 1992:69–90.

29. Bayes de Luna A, Coumel P, Leclercq JF. Ambulatory sudden cardiac death: mechanisms of production of fatal arrhythmia on the basis of data from 157 cases. Am Heart J 1989;117:151–9.

30. Luu M, Stevenson WG, Stevenson LW, Baron K, Walden J. Diverse mechanisms of unexpected cardiac arrest in advanced heart failure. Circulation 1989;80:1675–80.

31. Manolis AS, Estes NAM. Value of programmed ventricular stimulation in the evaluation and management of patients with nonsustained ventricular tachycardia associated with coronary artery disease. Am J Cardiol 1990;65: 201–5.

32. Winters SL, Ip J, Deshmukh P, et al. Determinants of induction of ventricular tachycardia in nonsustained ventricular tachycardia after myocardial infarction and the usefulness of the signal-averaged electrocardiogram. Am J Cardiol 1993;72:1281–5.