Prognostic value of late potentials in patients with congestive heart failure

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To investigate whether detection of ventricular late potentials could provide prognostic information in patients with congestive heart failure with or without bundle branch block, we prospectively obtained a signal-averaged ECG from 151 patients with congestive heart failure, using specific criteria in 57 patients with bundle branch block. Late potentials were detected in 49 patients (32·5%); their incidence was not significantly different in patients without (31%; 29 patients) or with bundle branch block (35%; 20 patients). Late potentials were present in 25 of 73 patients (34%) with idiopathic dilated cardiomyopathy, in 20 of 57 patients (35%) with ischaemic cardiomyopathy and in four of 21 patients (19%) with hypertensive heart disease (ns). Age, NYHA class, ejection fraction and use of amiodarone were not statistically different among patients with or without late potentials. In contrast, patients with late potentials had more past episodes of sustained ventricular tachycardia (8·2%; four patients) than those without late potentials (1·9%; two patients).

Twenty four hour ambulatory ECGs were obtained in 135 patients (89%). Non-sustained ventricular tachycardia was not correlated with the presence of late potentials found in 45 of 88 patients (51%) without late potentials and in 29 of 47 patients (62%) with late potentials (ns). The mean follow-up was 27 ± 12 months; 51 patients died, 31 from progressive congestive heart failure and 13 suddenly; seven prospectively had sustained ventricular tachycardia. The total mortality rate, the cardiac mortality rate and sudden death risk were not significantly related to the presence of late potentials; their incidence were respectively 35% (36 patients), 32% (33 patients) and 10% (10 patients) in patients without late potentials and 31% (15 patients), 23% (11 patients) and 6% (three patients) in those without late potentials. The incidence of sustained ventricular tachycardia during follow-up was 2% (two patients) in patients without late potentials and 10% (five patients) in those with late potentials.

The incidence of sustained ventricular tachycardia experienced by the patients before the study or seen during follow-up was significantly increased in the presence of late potentials: 18% (nine patients) vs 2% (two patients) in the absence of late potentials ($P<0·001$). Removal from the study of data from patients with bundle branch block, patients with severe congestive heart failure (NYHA 3 or 4) or patients taking amiodarone did not alter these results. Thus, signal-averaged ECG results only improved risk stratification for sustained ventricular tachycardia in patients with congestive heart failure and failed to identify patients at high risk for sudden death.
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Key Words: Signal averaged electrocardiogram, cardiac death, congestive heart failure.

Introduction

Patients with chronic heart failure are at a greater risk of succumbing to sudden death than any other definable subset of patients in cardiovascular medicine[1,2]. Although the survival of patients with non-ischaemic dilated cardiomyopathy is slightly better than that of patients with coronary artery disease, the incidence of sudden death is comparable[3,4]. Attempts to identify high-risk subgroups of patients with chronic heart failure from complex ectopic activity on the ambulatory electrocardiogram, arrhythmias on exercise stress testing, or by severity of left ventricular dysfunction have met with variable and limited success[5–9].

The signal-averaged electrocardiogram allows the detection of late potentials, which have been associated with delayed and disorganized ventricular activation, a substrate for reentrant ventricular tachycardia[10]. Several prospective studies have demonstrated that an abnormal signal-averaged ECG has predictive value for future ventricular events in patients with prior

myocardial infarction[11-15]. An increased incidence of late potentials on the signal-averaged ECG in patients with non-ischaemic dilated cardiomyopathy who present with ventricular arrhythmias has been previously reported[16-19], but whether the incidence of late potentials differs with the different aetiologies of congestive heart failure remains unclear.

The relationship between the presence of late potentials and severity of ventricular ectopy on ambulatory electrocardiograms in patients with chronic heart failure has yet to be discussed[20] and whether an abnormal signal-averaged ECG can provide predictive information in patients with congestive heart failure remains unclear. Previous studies by Meinertz et al.[21] and Middlekauff et al.[20] did not find the signal-averaged ECG to be predictive of sudden death or ventricular arrhythmias, whereas a recent study by Mancini et al.[22] found that the signal-averaged ECG identified patients with congestive heart failure at high risk for death and/or ventricular tachycardia. However, these studies, except that of Mancini et al. used small patient populations. Moreover, patients with bundle branch block were not analysed separately nor was the signal-averaged ECG performed in this group of patients, despite the frequency and prognostic value[23,24] of this electrocardiogram abnormality in patients with congestive heart failure.

The present prospective study was undertaken to determine if the presence of late potentials in patients with or without bundle branch block: (1) differs with the different aetiologies of congestive heart failure, (2) provides unique information for arrhythmias risk compared with assessment of ventricular ectopy on the ambulatory electrocardiogram and (3) identifies a subgroup of patients with congestive heart failure who are at particularly high risk of sudden death and/or ventricular arrhythmias.

Methods

Patients

Studies were performed in 151 consecutive patients with a dilated cardiomyopathy who had heart failure or underwent transplant evaluation between January 1990 and December 1993. Inclusion criteria were: New York Heart Association functional class II to IV congestive heart failure symptoms on discharge, a left ventricular ejection fraction <45%, and no permanent pacemaker or automatic implantable cardioverter defibrillator. Ejection fraction was obtained from radionuclide angiography, cardiac catheterization, or both during the initial evaluation. The type of extent of organic heart disease were defined by detailed history and physical examination, and left cardiac catheterization. One hundred and thirty-five patients (89%) were treated with diuretics, 140 (90%) with angiotensin converting enzyme inhibitors, 76 (50%) with digoxin; 68 patients (45%)

received amiodarone for atrial or ventricular arrhythmias. None received type I antiarrhythmic agents or investigation drugs.

Signal-averaged electrocardiogram

After informed consent was obtained, bipolar X, Y and Z leads were used to record approximately 250 ECG cycles (Marquette System). Each signal-averaged lead was filtered with the use of a bidirectional filter at 40 Hz. The three filtered signals were then combined into a vector magnitude $(X^2+Y^2+Z^2)^{1/2}$. The noise level was <0·4 µV in all cases. The filtered QRS duration (fQRS), root-mean-square voltage of the terminal 40 ms of the filtered QRS complex (RMS), and the duration of the terminal filtered QRS signal <40 µV (LAS) were measured. Abnormal values for these three parameters were defined as fQRS>120 ms, RMS<20 µV, and LAS>38 ms in the absence of bundle branch block and as fQRS ≥ 145 ms, RMS ≤ 17 µV, and LAS ≥ 55 ms in presence of bundle branch block[25]. Late potential was defined by the presence of two abnormal criteria out of three.

Ambulatory electrocardiogram

Twenty four hour electrocardiographic recordings were performed within 1 week of the signal-averaged ECG in 135 patients (89%). Two channel recordings were collected and analysed on a Marquette system. All arrhythmias were reviewed by the operator and one of the investigators. Only episodes of non-sustained ventricular tachycardia were analysed. Ventricular tachycardia was taken to be ≥ 3 consecutive ventricular beats at a rate of >120 beats . min⁻¹.

Follow-up

Patients were followed by one of the investigators or by referring physicians. In the event of death, information concerning the circumstances was obtained from the personal physician and family. End points of the study were death and sustained ventricular arrhythmias. Sudden death was unexpected death occurring within 1 h of a change in symptoms or during sleep[26]. The deaths of patients with progressive, symptomatic and/or haemodynamic deterioration were classified as resulting from progressive heart failure. Sustained ventricular tachycardia was prolonged ventricular tachycardia requiring an intervention for termination or associated with haemodynamic collapse.

Statistical analysis

Differences in characteristics among patient groups were compared by ANOVA or chi-squared analysis. For

comparison of continuous variables, independent tests were used. Probability of survival from the time of the signal-averaged ECG was analysed by the life-table method. Survival curves were compared using the log-rank test and Wilcoxon analysis. For survival analysis, patients who received a heart transplant or an automatic implantable cardioverter defibrillator were withdrawn from further follow-up on the date of intervention. All data are expressed as mean ± SD. A value of $P<0.05$ was considered significant.

Results

Clinical characteristics

The average age of the 126 men and 25 women was 59 ± 13 years (range 20–77 years). The aetiology of heart failure was idiopathic dilated cardiomyopathy in 73 (48%) patients, coronary artery disease in 57 (38%) patients and hypertensive heart disease in 21 (14%) patients. The average NYHA classification was 2·5 ± 0·5, with 48% in class II and 52% in class III to IV congestive heart failure. The mean left ventricular ejection fraction was 29 ± 8%. One hundred and thirty-two patients (87·4%) were in normal sinus rhythm, 19 (12·6%) were in atrial fibrillation. A bundle branch block was found in 57 patients (37·7%). Forty-nine patients had left bundle branch block and eight had right bundle branch block.

Signal-averaged electrocardiogram

Late potentials were detected in 49 of 151 patients (32·5%). Late potentials were present in 29 of 94 patients (31%) without bundle branch block and in 20 of 57 patients (35·1%) with bundle branch block (ns). Late potentials were detected in 25 of 73 patients with idiopathic dilated cardiomyopathy (34%), in 20 of 57 patients with ischaemic cardiomyopathy (35%), and in four of 21 patients with hypertensive heart disease (19%) (ns). Their incidence was independent of the aetiology of cardiac heart failure. In comparing patients with, to those without, late potentials, there were no significant differences in age (59 ± 14 vs 60 ± 11 years), NYHA class (2·6 ± 0·5 vs 2·5 ± 0·6), left ventricular ejection fraction (29 ± 8 vs 29 ± 8%) or amiodarone use (40·2 vs 55·1%). In contrast, a past history of sustained ventricular tachycardia appeared more frequent in the presence of late potentials being found in two patients (1·9%) without late potentials and in four patients (8·2%) with late potentials.

Ambulatory electrocardiograms

A 24 h ambulatory electrocardiogram revealed non-sustained ventricular tachycardia in 74 patients (55%). Late potentials were detected in 47 of 135 patients (35%)

who had an ambulatory electrocardiogram. Non-sustained ventricular tachycardia was present in 45 of 88 patients (51%) without late potentials and in 29 of 47 patients (62%) with late potentials, but this difference was not significant. This absence of correlation was independent of the aetiology of cardiac heart failure. In patients with idiopathic dilated cardiomyopathy, non-sustained ventricular tachycardia was present in 21 of 41 patients (51%) without late potentials and in 15 of 25 patients (60%) with late potentials (ns) and in patients with ischaemic cardiomyopathy, non-sustained ventricular tachycardia was present in 15 of 30 patients (50%) without late potentials, and in 11 of 19 patients (58%) with late potentials (ns). The presence of non-sustained ventricular tachycardia was not significantly related to the presence of bundle branch block.

Clinical outcome

Follow-up ranged from 3 to 40 months (mean 27 ± 9). Fifty-one patients died. The one-year mortality rate was 12% and the 2 year mortality rate 27%. The incidence of cardiac death was 29%, 31 deaths resulted from progressive heart failure and 13 deaths were sudden. Seven patients, only two of whom had a prior history of sustained ventricular tachycardia, during follow-up had sustained ventricular tachycardia. Five patients underwent heart transplantation and three implantation of a cardioverter defibrillator. The adverse events during follow-up were not clustered in any aetiologic subgroup. In fact, the total mortality rate and the arrhythmic events (sustained ventricular tachycardia and sudden death) were not significantly related to the aetiology of heart failure. Clinical characteristics of patients with cardiac adverse events are summarized in Table 1.

The total and cardiac mortality rates were not significantly increased in the presence of late potentials (Table 2), but the incidence of sustained ventricular tachycardia during follow-up appeared increased in the presence of late potentials: two patients (2%) without late potentials and five patients (10%) with late potentials prospectively had sustained ventricular tachycardia ($P=0.05$). The two patients without late potentials presented a past history of sustained ventricular tachycardia, whereas the five patients with late potentials had no past episodes of sustained ventricular tachycardia. Nevertheless, sudden death risk and the incidence of arrhythmic events, defined as sustained ventricular tachycardia or sudden death, were not significantly increased by the presence of late potentials. The incidence of cardiac events, defined as sustained ventricular tachycardia or cardiac death, was not also significantly related to the presence of late potentials: 35 patients (34%) without late potentials and 16 patients (33%) with late potentials had a cardiac event (ns). Finally, only the incidence of sustained ventricular tachycardia, reported in the patients before entering the study or observed in the patients during follow-up, was significantly increased

Table 1 Clinical characteristics of patients with cardiac adverse events, cardiac death or arrhythmic events (sustained ventricular tachycardia or sudden death), versus those without cardiac adverse events

	Cardiac death	No cardiac death	Arrhythmic events	No arrhythmic events
No	44	107	20	131
Age (years)	60 ± 12	59 ± 13	57 ± 12	59 ± 12
NYHA (class)	2·7 ± 0·6	2·5 ± 0·5	2·4 ± 0·6	2·6 ± 0·5
Ejection fraction (%)	26 ± 8	30 ± 8*	29 ± 8	29 ± 8
Bundle branch block (%)	41%	36%	40%	37%
Non sustained VT (%)	57%	54%	55%	55%
Late potentials (%)	25%	35%	40%	31%

NYHA = New York Heart Association; VT = ventricular tachycardia. *P<0·05.

Table 2 Clinical outcome of all patients, patients without or with bundle branch block, or patients with moderate or severe congestive heart failure. Arrhythmic events were defined as sustained ventricular tachycardia or sudden death. No significant difference was observed between patients without or with late potentials in any group

	All patients		Without BBB		With BBB		NYHA 2		NYHA 3/4	
	LP −	LP+	LP −	LP+	LP −	LP+	LP −	LP+	LP −	LP+
n	102	49	65	29	37	20	46	26	56	23
Deaths	36 (35)	15 (31)	22 (34)	9 (31)	14 (38)	6 (30)	17 (37)	5 (19)	19 (34)	10 (43)
Cardiac deaths	33 (32)	11 (23)	21 (32)	5 (17)	12 (32)	6 (30)	15 (33)	4 (15)	18 (32)	7 (30)
Sudden deaths	10 (10)	3 (6)	6 (9)	1 (4)	4 (11)	2 (10)	7 (15)	1 (4)	3 (5)	2 (9)
Arrhythmic events	12 (12)	8 (16)	7 (11)	5 (17)	5 (13)	3 (15)	8 (17)	5 (19)	4 (7)	3 (13)

LP − = without late potentials; LP+ = with late potentials; BBB = bundle branch block; NYHA = New York Heart Association. Values in parentheses indicate percentages.

Table 3 Predictive values of the signal-averaged electrocardiogram

	Sensitivity	Specificity	+ Predictive value	− Predictive value
Deaths	29·4%	66·0%	30·6%	64·7%
Cardiac deaths	29·5%	66·3%	26·5%	66·3%
Arrhythmic events	40·0%	68·7%	16·3%	88·2%

Arrhythmic events were defined as sustained ventricular tachycardia or sudden death

in the presence of late potentials: 2% (two patients) in the absence of late potentials vs 18% (nine patients) in the presence of late potentials ($P<0·001$). The predictive value of signal-averaged electrocardiographic analysis to prospectively predict the clinical occurrence of death and arrhythmic events are summarized in Table 3.

The role of bundle branch block: inclusion of 57 patients with bundle branch block did not alter the results. Analysis of the data after elimination of patients with bundle branch block yielded identical findings (Table 2). The role of severity of congestive heart failure: inclusion of 79 patients with advanced congestive heart failure (NYHA class III–IV) did not alter the results. Analysis of the data of the 72 patients with moderate congestive heart failure (NYHA class II) yielded identical findings (Table 2). Role of amiodarone: 68 of 151 patients received amiodarone. Patients treated with this

drug were significantly older ($62 ± 10$ vs $57 ± 14$, $P<0·05$), but no statistically significant difference was noted between patients with or without amiodarone in regard to NYHA classification ($2·6 ± 0·6$ vs $2·5 ± 0·5$) and ejection fraction ($28·5 ± 8·7\%$ vs $28·4 ± 8·7\%$). But patients treated with amiodarone had significantly more episodes of non-sustained ventricular tachycardia ($63·5$ vs $36·5\%$, $P<0·01$) during the ambulatory electrocardiogram. Use of amiodarone did not alter the results; analysis of the data after elimination of patients receiving amiodarone yielded identical findings. For example, the absence of the difference in the total mortality rate of patients with or without late potentials persisted in the group of patients without amiodarone: 16 of the 61 patients (26%) without late potentials and five of the 22 patients (23%) with late potentials died (ns). This absence of correlation between mortality rate and late
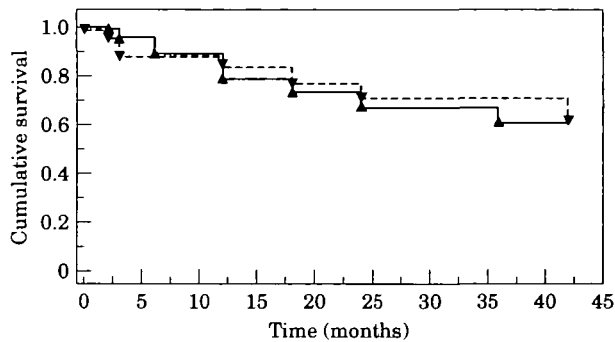
Figure 1 Survival curves comparing patients with congestive heart failure without (——) or with (– – –) late potentials. Cumulative survival was not significantly different in patients without or with late potentials ($P=0.754$).
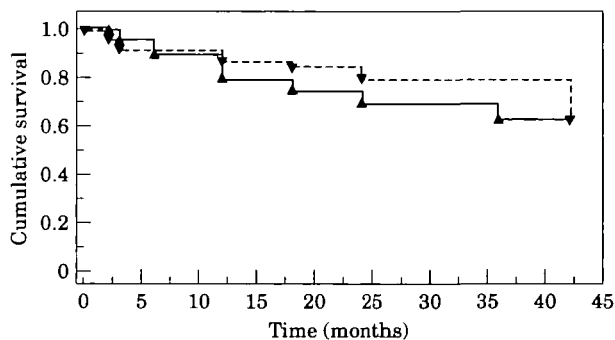

Figure 2 Cumulative freedom from cardiac events defined as cardiac death or heart transplantation in patients with congestive heart failure without (——) or with (– – –) late potentials. The cardiac risk was not significantly increased by the presence of late potentials ($P=0.439$).

potentials was also found in the group of patients treated with amiodarone: 20 of the 41 patients (49%) without late potentials and 10 of the 27 patients (37%) with late potentials died (ns).

Univariate analysis

The presence of late potentials did not predict an adverse outcome by univariate analysis. Cumulative survival, cardiac event-free survival with events defined as cardiac death or heart transplant, cumulative freedom from arrhythmic events defined as sustained ventricular tachycardia or sudden death were not significantly different in patients without or with late potentials (Figs 1 and 2).

Discussion

In the present study, we examined whether the signal-averaged ECG, a technique previously shown to be predictive of sudden death in patients with prior

myocardial infarction[11–15], could provide similar prognostic information in patients with congestive heart failure. In fact, mortality rates in patients with heart failure are high, and approximately 40% of deaths occur suddenly and unexpectedly[1]. Sudden death risk correlated with the severity of congestive heart failure[8,27], but attempts to risk-stratify patients further with non-invasive and invasive testing have had limited success[5–9]. In retrospective studies of patients with coronary artery disease or idiopathic dilated cardiomyopathy, the presence of late potentials distinguished patients with from those without ventricular tachycardia, regardless of the aetiology of heart disease[16,28]. We prospectively followed 151 patients with congestive heart disease who presented to our clinic over a 27-month period. From this study, several significant observations can be made.

The incidence of late potentials appears independent of the aetiology of congestive heart failure. In fact, late potentials were found in 34% of patients with idiopathic dilated cardiomyopathy, and in 35% of patients with ischaemic heart disease. Previously a study by Middlekauff et al.[20] found that late potentials occur more frequently in patients with ischaemic than with non-ischaemic congestive heart failure. However, this study used a smaller patient population: 22 patients with an idiopathic dilated cardiomyopathy. Furthermore, prospective adverse events in patients with late potentials were not clustered in any aetiological subgroup, implying a common mechanism for arrhythmia generation. Interstitial fibrosis and hypertrophy are frequently seen on endomyocardial biopsies in patients with congestive heart failure. This can result in abnormal impulse conduction with slow ventricular activation.

The ambulatory electrocardiogram has been used with variable success in risk stratification for sudden death in patients with congestive heart failure[6–9]. In our study, late potentials were not significantly related to the presence of non-sustained ventricular tachycardia on the ambulatory electrocardiogram. Our findings support those of Middlekauff et al. who found no correlation between the severity of ventricular ectopic activity and the results of the signal average ECG[20]. In contrast, Fauchier et al.[29] found a significantly higher incidence of severe ventricular premature beats in patients with idiopathic dilated cardiomyopathy and late potentials. Moreover, in previous works late potentials were not related to the frequency of ventricular ectopic activity[20,29], so it is possible that each test assesses different components of arrhythmia susceptibility. The signal-averaged ECG identifies areas of slow conduction potentially capable of supporting a reentry circuit, and the ambulatory electrocardiogram identifies ventricular beats that may supply the trigger for reentrant tachycardia. In fact, the combination of the two abnormalities may identify a high-risk group among those with congestive heart failure and also after myocardial infarction[15].

An important finding of our study is that the results of the signal-averaged ECG only improved risk

stratification for sustained ventricular tachycardia in patients with congestive heart failure, but failed to identify patients at high risk for sudden death. Furthermore, cardiac mortality was not increased in the presence of late potentials in our patients. Results in the literature remain controversial. Ohnishi *et al.*[30] and Mancini *et al.*[22] described, respectively, a high incidence of prospective arrhythmias and sudden death in 54 and 20 patients with a dilated cardiomyopathy and abnormal signal-averaged ECG. Previous studies by Meinertz *et al.*[21] and Middlekauff *et al.*[20] did not find the signal-averaged ECG to be predictive of sudden death or ventricular arrhythmias. However, these studies used smaller patient populations. Meinertz *et al.*[21] studied 30 patients with non-ischaemic dilated cardiomyopathy, only three of whom had abnormal signal-averaged ECGs. The number of outcomes was too small in these studies to reach any firm conclusions. A recent study by Silverman *et al.*[31] confirmed the absence of the prognostic value of the signal-averaged ECG in congestive heart failure; in 200 patients with severe heart failure due to non-ischaemic or ischaemic cardiomyopathy the presence of late potentials did not significantly increase total mortality. However, in this study, the cause of death and the incidence of sustained ventricular tachycardia were not studied.

Large studies of sudden death victims, which included patients with various degree of ventricular dysfunction, have shown that sudden death is due to ventricular tachycardia degenerating to ventricular fibrillation[32]. However, in patients with congestive heart failure, the ambulatory electrocardiogram, electrophysiological testing for inducible ventricular tachycardia and now the signal-averaged ECG have been poor predictors of sudden death risk[5–9,20,21,33]. One possible explanation is that ventricular tachycardia is responsible for only a subset of sudden deaths in congestive heart failure. Patients with congestive heart failure are also at risk for other potentially disastrous events that may be clinically manifested by sudden death. In fact, bradyarrhythmias and electromechanical dissociation were common initial rhythms at unexpected cardiac arrest in patients with congestive heart failure[34]. Furthermore in these patients, a variety of causes of sudden death was found, including myocardial infarction, pulmonary and systemic thromboembolism[34]. In our patients, sudden death occurred out of hospital and was unmonitored, therefore, the relative contribution of ventricular tachycardia is unknown.

Study limitations

The mortality rate in our study appears surprisingly low with a 1-year mortality of 12% and a 2 year mortality of 27%. Mortality rates for patients were congestive heart failure range from 11% to 48%[3,8,9,22,24,35,36]. But the majority of these patients was not receiving vasodilator therapy, which has recently been shown to significantly prolong survival in patients with heart failure[35,37].

Cardiac transplantation was also not widely available at the time of these studies. Thus, the improvement in our survival may be accounted for by the recent advances in heart failure therapy.

The incidence of sudden death in our study was low, with only 13 sudden deaths in the 151 patient cohort. The incidence of sudden death in patients with congestive heart failure in past reports ranges from 4% to 88%[3,8,9,22,36,37–39]. Our experience is similar to that of Maskin *et al.*[39] and Mancini *et al.*[22] who described a 4% incidence of sudden death. Frequent monitoring of electrolyte levels may have helped to decrease the incidence of sudden death in our population[40], widespread use of angiotensin converting enzyme inhibitors may also have helped to limit our incidence of sudden death. In fact, recent studies have found a significant reduction of the incidence of sudden death in congestive heart failure by the use of angiotensin converting enzyme inhibitors[41]. Furthermore, the absence of the use of type I antiarrhythmic medications and the extensive use of amiodarone (68 patients) may also have helped to limit the incidence of sudden death. In fact, the proarrhythmic effects of antiarrhythmic drugs are increased in patients with heart failure[42] although low-dose amiodarone may have a beneficial effect[40,43–45]. However, in our study amiodarone use did not differ between patients with and without late potentials.

Analysis of the signal-averaged ECG in patients with bundle branch block could conceivably alter the results of this study. In fact, the signal-averaged ECG was not performed in this group of patients by Mancini *et al.*[22] and Silverman *et al.*[31]. However, in congestive heart failure, bundle branch block is frequent, found in about 30% of patients, and may be an independent factor of the poor prognosis for patients with dilated cardiomyopathy[23,24]. Using specific criteria to define late potentials[25], it seems possible to include patients with bundle branch block in studies undertaken to determine the predictive values of the signal-averaged ECG in congestive heart failure, whereas analysis of the data of patients without or with bundle branch block yielded identical findings. Nevertheless, in the future, spectral turbulence analysis of the signal-averaged ECG may be more effective than time-domain analysis in patients with bundle branch block and congestive heart failure[46].

Clinical implications

The results of this study have several important clinical implications. First, late potentials are common in patients with congestive heart failure and their incidence appears independent of the aetiology of heart failure. Secondly, the presence of late potentials is not significantly related to the severity of ventricular ectopy in ambulatory electrocardiogram in patients with congestive heart failure, suggesting that each test may provide unique information regarding arrhythmia risk. Thirdly, the results of the signal-averaged ECG only improved

risk stratification for sustained ventricular tachycardia in patients with congestive heart failure, but failed to identify patients with congestive heart failure at high risk for sudden death. This is consistent with the heterogeneous aetiologies of sudden death in congestive heart failure, ventricular tachycardia being only one of many possible mechanisms. Fourthly, using specific criteria of definition of late potentials, inclusion of patients with bundle branch block did not alter the results of the signal-averaged ECG.

The signal-averaged ECG appears to provide a weak non-invasive research tool to risk-stratify patients with heart failure but may help in the future to establish appropriate antiarrhythmic therapy with drugs and/or devices in these patients.

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