

Postextrasystolic U Wave Augmentation, a New Marker of Increased Arrhythmic Risk in Patients Without the Long QT Syndrome

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Objectives. We attempted to determine the correlation between the presence of postextrasystolic changes in the STU segment and a history of sustained ventricular arrhythmias.

Background. Postextrasystolic U wave augmentation (a marked increment in U wave amplitude after premature ventricular complexes [PVCs]) is an adverse prognostic sign in the "pause-dependent long QT syndrome." However, the prevalence of postextrasystolic changes in patients without the long QT syndrome is unknown.

Methods. We compared the configuration of the STU segment of the postextrasystolic beat (the sinus beat after a PVC) with the STU configuration during sinus rhythm in three patient groups: 1) 41 patients with spontaneous ventricular tachycardia/fibrillation (VT/VF) (VT/VF group), 2) 63 patients with heart disease and high grade ventricular arrhythmias (control group), and 3) 29 patients with high grade ventricular arrhythmias but no heart disease (reference group).

Results. Postextrasystolic T wave changes did not correlate with a history of ventricular tachyarrhythmias. However, postextrasystolic U wave changes were more common among the patients with VT/VF than among control subjects (39% vs. 8.7%, $p < 0.001$). By logistic multiple regression analysis, a low left ventricular ejection fraction ($p < 0.001$) and postextrasystolic U wave changes ($p < 0.005$) were independent predictors of ventricular tachyarrhythmias.

Conclusions. Postextrasystolic T wave changes are common and lack predictive value. Postextrasystolic U wave changes may be a specific marker of a tendency to the development of spontaneous ventricular arrhythmias. Prospective studies should be performed to confirm this association.

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Postextrasystolic U wave augmentation, that is, a marked increment in U wave amplitude after premature ventricular complexes (PVCs), is a well recognized adverse prognostic sign in patients with the "pause-dependent long QT syndrome": Patients with a prolonged QT interval showing bizarre TU complexes after PVCs are prone to the development of torsade de pointes and ventricular fibrillation (1-3). Also, some evidence (1,3) suggests that the increment in U wave amplitude after a PVC, rather than lengthening of the QT interval, is a marker for arrhythmic risk. However, the prevalence and the prognostic significance of minor postextrasystolic U wave changes in patients without the long QT syndrome is less clear.

Previous studies on the behavior of the STU segment after a PVC in patients without the long QT syndrome (4-12) have

mainly focused on the incidence of T wave changes. The clinical interpretation of these T wave changes (also known as "post-pause" T changes because they follow pauses related to sinus arrhythmia [10], atrial premature complexes or atrial fibrillation [6] has changed over the years. Originally, postextrasystolic T wave changes, including T wave inversion, were considered to be markers of heart disease (4-7). However, more recent studies, (9-12) found T wave changes to be just as common among patients with an apparently normal heart. Only the study of Myburgh (10) specifically looked at the incidence of U wave changes in patients with a normal QT interval. In a large cohort of healthy military personnel, he found postextrasystolic U wave abnormalities in only 3% of subjects with multiple PVCs, but T wave changes occurred in 36% of these patients. The latter rate is comparable to the 26% to 57% incidence rate of T wave changes after spontaneous PVCs reported by others (5,8,9).

In this study, we evaluated the incidence of postextrasystolic repolarization abnormalities among patients with a history of ventricular arrhythmias not related to the long QT syndrome. Specifically, we studied whether the postextrasystolic beats of these patients would reveal morphologic abnormalities reminiscent of those that occur spontaneously in patients with the

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Abbreviations and Acronyms

ECG	=	electrocardiogram, electrocardiographic
LVEF	=	left ventricular ejection fraction
PVC	=	premature ventricular complex
QTc	=	corrected QT interval
VT/VF	=	ventricular tachycardia/ventricular fibrillation

long QT syndrome (13,14) and would predict ventricular fibrillation.

Methods

We compared the configuration of the STU segment of the sinus beat immediately after a PVC with the STU segment configuration of at least 3 sinus beats preceding it, in all the electrocardiograms (ECGs) of the following patient groups: 1) patients with out-of-hospital ventricular fibrillation or hypotensive ventricular tachycardia not related to acute myocardial infarction (VT/VF group); 2) patients with organic heart disease, multiple PVCs but without a history of sustained ventricular arrhythmias (control group); and 3) patients with multiple PVCs but no organic heart disease or sustained ventricular arrhythmias (reference group).

Patients. The VT/VF group consisted of 41 patients (29 men, 12 women) consecutively selected from our population of patients referred for implantation of automatic defibrillator. All met the following inclusion criteria: 1) The index spontaneous arrhythmia was poorly tolerated and required immediate intervention for termination; and 2) the arrhythmia occurred in the absence of metabolic abnormalities or drug treatment that could potentially lead to arrhythmogenic QT prolongation, including treatment with class I or class III antiarrhythmic drugs. Furthermore, to eliminate the confounding factor of drugs on postextrasystolic QT prolongation, only traces recorded in the absence of treatment with class I or class III antiarrhythmic drugs were analyzed (see later). The control group, randomly selected among hospital patients in a bed with arrhythmia monitoring, consisted of 63 patients (43 men, 20 women) with organic heart disease admitted to the hospital for elective cardiac catheterization, cardiovascular surgery, evaluation of chest pain (in the absence of acute myocardial infarction) or treatment of heart failure. We also studied the incidence of postextrasystolic TU abnormalities in a reference group of 29 patients (9 men, 20 women) with multiple PVCs and no organic heart disease (as assessed by history, examination, ECG and echocardiogram) who were admitted to the hospital for electrophysiologic evaluation of supraventricular arrhythmias. None of the patients in the control or reference groups had a history of syncope or was receiving drugs potentially affecting the QT interval. Additional exclusion criteria for all groups were 1) a basic rhythm other than sinus rhythm (including continuous or intermittent atrial or ventricular pacing), 2) ventricular pre-excitation, and 3) the presence of mitral valve prolapse. We excluded patients with mitral

prolapse because the possible association between this syndrome and the congenital long QT syndrome (1) could potentially lead to postextrasystolic QTU wave abnormalities.

ECGs. Digitized 12-lead ECGs recorded at the time of electrophysiologic evaluation for ventricular or supraventricular arrhythmias (VT/VF and control group, respectively) or cardiac catheterization were scrutinized for spontaneous PVCs occurring before catheter manipulation. In addition, all available ECGs and Holter ambulatory ECG recordings were reviewed. We did not analyze traces showing acute ST segment elevation or depression, traces with a postextrasystolic escape other than sinus rhythm or traces showing increased baseline noise, ventricular bigeminy, trigeminy or ventricular tachycardia.

Definitions. We used the following definitions: *Postextrasystolic complex* is the first sinus complex after a PVC. *Coupling interval* is the RR interval between a PVC and the preceding sinus complex. *Postextrasystolic pause* is the RR interval between a PVC and the postextrasystolic complex. *Prematurity index* is the coupling interval divided by the RR interval of the sinus complexes preceding the PVC. *Pause/coupling ratio* is the postextrasystolic pause divided by the coupling interval. *Pause/RR interval* is the postextrasystolic pause divided by the mean RR interval of the sinus beats preceding the PVC. *QT dispersion* is the difference between the maximal and the minimal QT interval in any lead of a 12-lead ECG during sinus rhythm (15).

Scoring. Three investigators who had no knowledge of any patient name, group assignment or clinical data reviewed all traces independently. Each postextrasystolic sinus beat was graded according to the following prospectively defined scores: *Grade 0* (no changes): The STU segment of the postextrasystolic beat was identical to the STU segment of the sinus complexes preceding the PVC (Fig. 1). *Grade 1* (questionable changes): The difference between the STU segment of the postextrasystolic beat and the preceding sinus beats did not reach the requirements for grade 2 or 3; the postextrasystolic TU changes were not reproducible and therefore it was not clear whether the postextrasystolic changes were attributable to random noise. *Grade 2* (T wave changes): There was a definitive change in the initial part of the STU segment (the peak of the T wave), including a ≥ 0.1 -mV increase or decrease in T wave amplitude (as compared with T waves during basic sinus rhythm) or postextrasystolic T wave inversion (Fig. 2). *Grade 3* (U wave augmentation): After a PVC there was a definite change in the terminal part of the STU segment including the appearance of a new U wave (defined as a new positive deflection ≥ 0.1 mV in amplitude any time after the peak of the T wave) or an increment ≥ 0.1 mV in the amplitude of U waves clearly present during basic sinus rhythm (Fig. 3). For patients with negative T waves or biphasic STU segments during basic sinus rhythm, appearance of a new terminal positive deflection or a ≥ 0.1 -mV increment in the amplitude of the terminal positive repolarization wave was also considered a U wave change (Fig. 3B).

Each patient received a "patient score," which was the

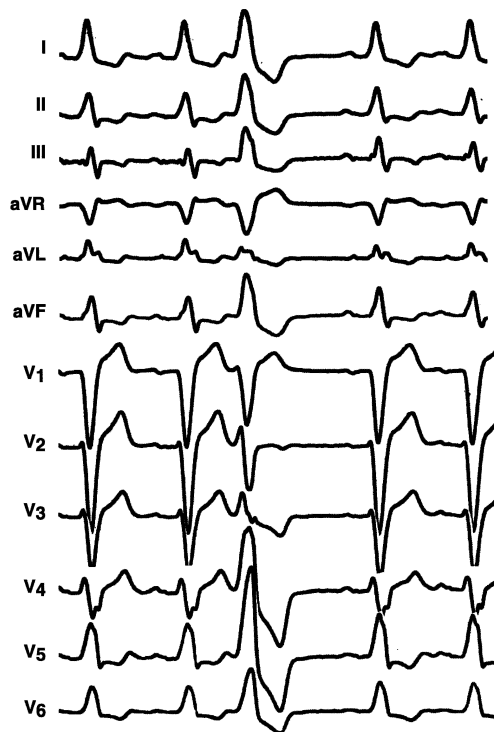


Figure 1. Simultaneous 12-lead ECG from a patient with dilated cardiomyopathy and left bundle branch block. The STU segment of the postextrasystolic beat is the same as the STU segment of the preceding sinus complexes (grade 0).

highest grade awarded to any of his or her postextrasystolic beats by at least two investigators. Each postextrasystolic beat was numbered sequentially. Thus, the grading given by each reviewer to each postextrasystolic beat could be compared. Intraobserver variability was assessed in a subset of traces with 1,095 PVCs that were read twice by one investigator. This subset included beat samples with all the different grades from all patients. Only beats awarded the same scoring at least three times by different investigators (including the subset of beats graded twice) were used to assess the ECG predictors of

Figure 2. Simultaneous ECG (leads shown are V₁, V₄, V₅) showing postextrasystolic T wave changes (grade 2); the amplitude of the T wave increases after a PVC in leads V₄ and V₅ (arrows), and there is postextrasystolic inversion of the T wave in lead V₁ (arrowhead).

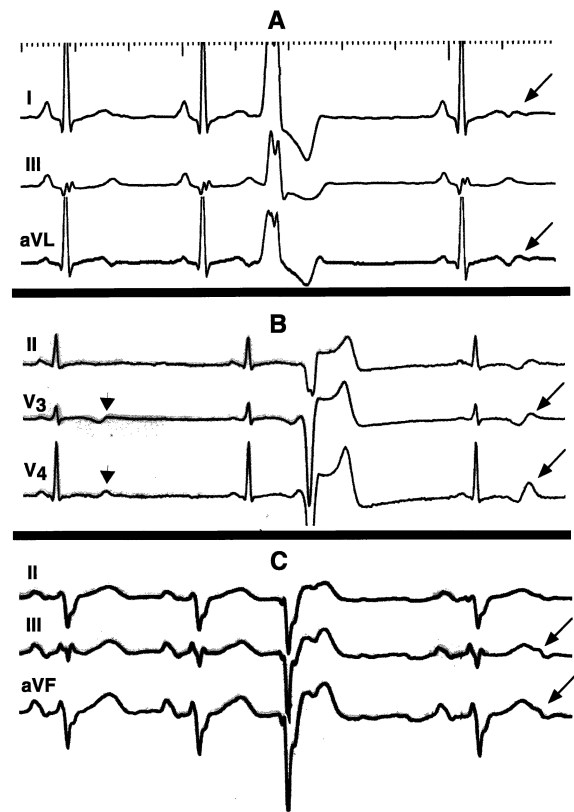
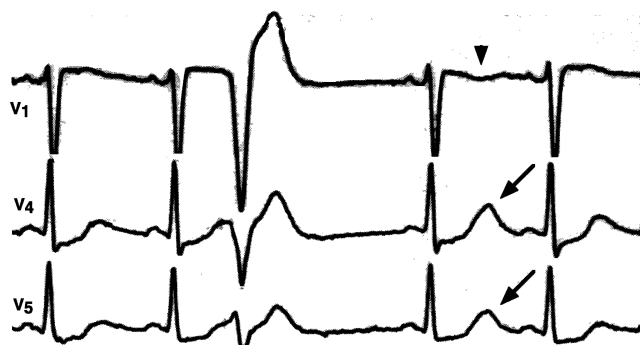


Figure 3. Three examples of postextrasystolic changes in the terminal repolarization wave (grade 3). **A**, Appearance of new U waves after a premature ventricular beat (arrows). **B**, Before the premature beat, the sinus beats have a biphasic STU segment with negative T waves (lead V₃) and a terminal positive deflection (arrowheads). The postextrasystolic beat shows augmentation of the amplitude of the terminal positive deflection (arrows) and is similar to the QT interval configuration commonly seen during basic sinus rhythm in patients with the long QT syndrome. **C**, Appearance of a new positive wave after the peak of the T wave (arrows). The configuration of the QTU segment of the postextrasystolic beat is similar to the QT configuration described as "T wave humps" during basic sinus rhythm in patients with the long QT syndrome.

postextrasystolic TU changes. All intervals were measured at a paper speed of 25 mm/s.

Statistics. The following variables were analyzed for their value in predicting a history of VT/VF among patients with organic heart disease: 1) clinical variables (age, gender, coronary artery disease, history of myocardial infarction, left ventricular ejection fraction and use of beta-adrenergic blocking agents); 2) ECG variables (PR interval, corrected QT [QTc] interval, QT dispersion, coupling interval, postextrasystolic pause, prematurity index, postextrasystolic index); 3) postextrasystolic T wave changes (grade 2); and 4) postextrasystolic U wave augmentation (grade 3). Univariate predictors were examined by chi-square test for discrete variables and *t* test and analysis of variance for continuous variables. The Student *t* test with the Bonferroni correction for multiple comparisons was used to compare differences between groups identified by analysis of variance. All variables listed in Table 1 were

Table 1. Clinical and Electrocardiographic Characteristics of Study Patients

	Groups		
	VT/VF (n = 41)	Control (heart disease) (n = 63)	Reference (normal heart) (n = 29)
Mean age (yr)	61 ± 14	65 ± 14	54 ± 14
Men	29 (71%)	43 (68%)	9 (45%)
Coronary artery disease	34 (83%)	48 (76%)	—
LVEF (%)	30 ± 11	44 ± 14**	61 ± 5†††
Beta-blocker therapy	4 (10%)	40 (63%)	2 (7%)
PR interval (ms)	183 ± 50	169 ± 40	145 ± 30†
QRS (ms)	133 ± 14	125 ± 14	96 ± 20
QTc (ms)	436 ± 30	435 ± 30	430 ± 30
QT dispersion (ms)	65 ± 19	56 ± 18*	53 ± 17††
PVCs analyzed patient (no.)	22 ± 15	28 ± 20	40 ± 25††

*p < 0.05, **p < 0.001, VT/VF group versus control group. †p < 0.01, ††p < 0.005, †††p < 0.001, VT/VF group versus reference group. Data presented are mean value ± SD or number (%) of patients. LVEF = left ventricular ejection fraction; PVC = premature ventricular contraction; QTc = corrected QT interval; VT/VF = ventricular tachycardia/ventricular fibrillation.

included in a multivariate analysis. Variables that were not statistically associated with a history of spontaneous VT/VF were removed in a stepwise fashion from the multivariate model until only the independent variables remained. This multivariate analysis was performed by using JMP 3.1.5 statistical software. Sensitivity, specificity and likelihood ratio were calculated for each univariate predictor. Likelihood ratio was defined as sensitivity/(1 - specificity) (16). Statistical significance was defined as a p value < 0.05.

Results

Patient characteristics (Table 1). Forty-one patients (29 men, 12 women) with spontaneous ventricular fibrillation (n = 23) or hypotensive ventricular tachycardia (n = 18) who were not receiving antiarrhythmic drugs at the time of the index arrhythmia or during ECG analysis were studied. They were comparable to the control group in age, gender, incidence of coronary heart disease and QRS and QTc intervals. Patients with ventricular tachycardia or fibrillation had a lower left ventricular ejection fraction, received beta-blocker therapy less often and had larger QTc dispersion values than did patients in the control and reference groups.

Postextrasystolic TU wave changes. Postextrasystolic T wave changes (grade 2) were observed in all patient groups (Fig. 4). There was no correlation between the presence of T wave changes (including postextrasystolic T wave inversion) and a history of sustained ventricular arrhythmias, the presence of coronary heart disease or impaired left ventricular function.

Postextrasystolic U wave augmentation (grade 3) was more common among patients with ventricular tachycardia or fibrillation (39%) than among patients in the control (8.7%) or

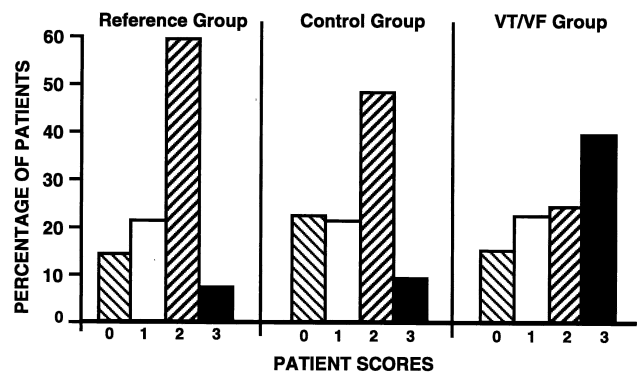


Figure 4. Distribution of patients according to their patient score. For definitions of groups and scores, see Methods.

reference (7%) group (p < 0.001) (Fig. 4). Among patients with coronary heart disease, postextrasystolic U wave augmentation was again more common in patients with VT/VF than in control subjects (38% vs. 8.3%, p < 0.001).

Multiple regression analysis. Patient and control groups differed with respect to left ventricular ejection fraction (LVEF), beta-blocker use and QT dispersion (Table 1). However, multiple logistic regression analysis, which included all the variables from Table 1 in addition to the presence of postextrasystolic U wave augmentation, revealed that only LVEF (p < 0.001) and postextrasystolic U wave augmentation (p < 0.005) were independently associated with a history of VT/VF, whereas QTc and QT dispersion were not.

Accuracy. The sensitivity and specificity of postextrasystolic U wave augmentation for predicting a history of VT/VF were 0.39 and 0.91, respectively. The likelihood ratio (4.3) was greater than that of other prognostic tests in our study patients (Table 2).

When their data were reviewed a second time by the same observer, five control subjects and nine patients with ventricular arrhythmias were assigned to a different group with respect to U wave changes. The intraobserver variability for predicting a history of VT/VF according to the presence of postextrasystolic U wave augmentation was 11%.

Table 2. Sensitivity and Specificity of Different Tests for Predicting Sustained Ventricular Tachycardia/Fibrillation in Study Patients*

Test	Sensitivity	Specificity	Likelihood Ratio
Postextrasystolic U wave augmentation	0.39	0.91	4.33
LVEF <0.40	0.67	0.73	2.45
LVEF ≤0.40	0.74	0.69	2.41
QRS ≥112 ms	0.44	0.76	1.81
QT dispersion ≥60 ms	0.67	0.75	2.63
QT dispersion ≥80 ms	0.23	0.85	1.52
QTc ≥450 ms	0.38	0.72	1.39
QTc ≥440 ms	0.60	0.54	1.34

*Patients with sustained ventricular tachycardia or fibrillation and control subjects with high grade ventricular arrhythmias and organic heart disease. Abbreviations as in Table 1.

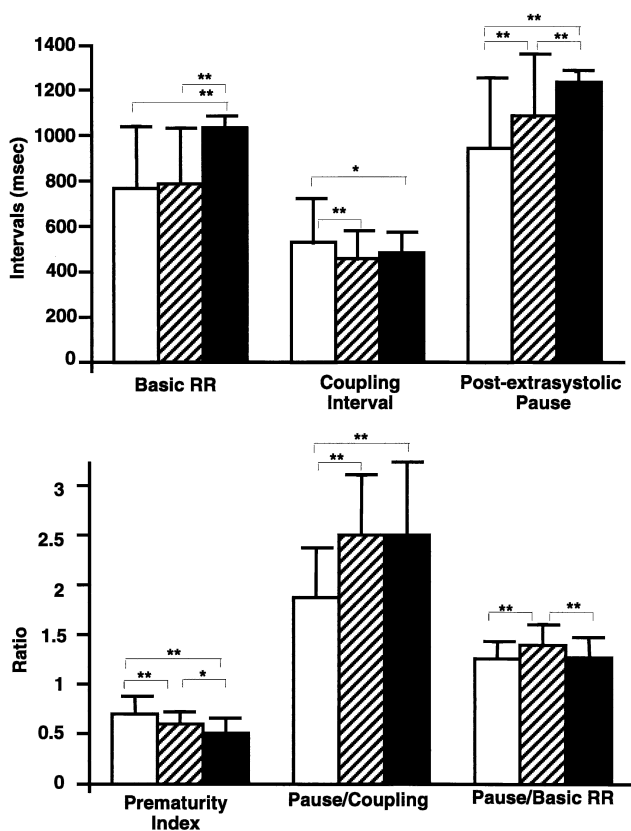


Figure 5. Bar graph showing the correlation between RR intervals and the presence of postextrasystolic U wave changes (solid bars), T wave changes (hatched bars) and no changes (open bars) in all patient groups. Basic RR = RR interval of the sinus beats preceding the PVC; coupling interval = RR interval between the PVC and the preceding sinus beat; postextrasystolic pause = RR interval between the PVC and the postextrasystolic sinus beat; prematurity index = the coupling interval divided by the RR interval of the sinus complexes preceding the PVC; pause/coupling = the postextrasystolic pause divided by the coupling interval; pause/basic RR = the postextrasystolic pause divided by the RR interval of the sinus beats preceding the PVC. * $p < 0.03$, ** $p < 0.005$.

ECG predictors of postextrasystolic changes (Fig. 5). Postextrasystolic U wave augmentation was more common when PVCs occurred during sinus bradycardia than when they occurred during faster sinus rates. For all patients, both postextrasystolic T wave and U wave changes were favored by PVCs with relatively short coupling intervals and long postextrasystolic pauses. In fact, the coupling intervals of PVCs leading to postextrasystolic T wave changes were slightly shorter than the coupling intervals of the PVCs leading to U wave changes ($p = \text{NS}$). Because of the sinus bradycardia that commonly preceded the PVCs leading to U wave changes, the sudden change in cycle length was of greater magnitude for PVCs leading to U wave changes (prematernity index 0.7 ± 0.1 , 0.6 ± 0.1 and 0.5 ± 0.2 for PVCs with no changes and postextrasystolic T wave and U wave changes, respectively, $p < 0.001$ and $p < 0.03$). Finally, the postextrasystolic pauses leading to U wave augmentation were longer than the pauses

preceding postextrasystolic T wave changes. This observation may reflect the slower basic sinus rate during U wave than during T wave changes because the ratio between the coupling interval of the PVC and the ensuing compensatory pause was similar for complexes with T and U wave changes.

Discussion

Repolarization abnormalities are recognized ECG risk markers for cardiovascular mortality and sudden cardiac death. This prognostic value of QT interval analysis has been established for many patient groups, including adults with no history of heart disease (17) and patients with healed myocardial infarction (18), heart failure (19), congenital or acquired complete heart block (20,21) or proarrhythmic events (1). These data are based on studies in which the QTU segment was scrutinized during basic sinus rhythm, excluding PVCs and postextrasystolic beats from analysis. Our study shows that some repolarization abnormalities that become evident only after a PVC may offer important additional prognostic information.

Present study. We studied a cohort of patients with poorly tolerated spontaneous ventricular arrhythmias. To eliminate any confounding effect of antiarrhythmic drugs on postextrasystolic QT prolongation, we included only patients who had ventricular tachyarrhythmias in the absence of drugs and who had not received class I or class III antiarrhythmic drugs at the time of recording of the ECG used for the present analysis. Patients with organic heart disease and multiple PVCs but without sustained arrhythmias were studied for comparison. As expected, the patients and control subjects differed in several characteristics, including LVEF and QT dispersion. These differences could have biased our results. However, stepwise logistic regression analysis suggested that postextrasystolic repolarization abnormalities have independent value for identifying patients with sustained ventricular arrhythmias.

The main findings of our study are that 1) postextrasystolic changes limited to the T wave are very common and have no predictive value; 2) postextrasystolic U wave changes, although less common, appear to be a specific marker of a tendency to the development of spontaneous ventricular arrhythmias. These results are in accordance with previous studies reporting that T wave changes are common (4-8) and U wave changes are rare (10) after PVCs.

T waves, U waves and postextrasystolic changes. T waves have long been recognized to be the ECG representation of ventricular repolarization (1). However, the physiology underlying the formation of U waves has been more elusive (22). Recently, the presence of a subtype of myocardial cells demonstrating an action potential duration long enough to match the timing of the U wave was demonstrated in dogs (23) and, subsequently, in humans (24). The action potential duration of the M cells, which occupy the subepicardial region and represents ~30% of the myocardial mass (24), is more rate dependent than is the action potential of endocardial and epicardial cells (23,24), providing a reasonable explanation for the long

recognized U wave accentuation that occurs during a slow heart rate (1,22-24).

The sudden decrease and subsequent increase in cycle length associated with a PVC and its postextrasystolic pause will affect the formation of both T and U waves in several ways. During normal ventricular activation, the duration of ventricular repolarization is shorter in myocardial areas activated last (basal and epicardial areas) than in those depolarized first (apical and endocardial). This accounts for the usual concordance of the QRS and T wave vectors. However, this relation between activation sequence and duration of repolarization is disturbed during ectopic ventricular activation (25), leading to T wave alterations in the PVC and probably the postectopic beat. Also, the step increase in cycle length associated with the postextrasystolic pause will lead to an especially prolonged action potential of the postextrasystolic beat (26,27) because the action potential duration is affected predominantly by the preceding diastolic interval (28). In the case of a postextrasystolic beat, the majority of the postextrasystolic pause is, in fact, a long diastolic interval because the action potential duration of the preceding beat (the PVC) was short (especially if the coupling interval was short) (28). Moreover, the alterations in ventricular refractoriness in myocardial cells after sharp changes in cycle length may be more irregular than those of the His-Purkinje tissue (29).

Because the action potential duration and refractoriness of the M cells are more affected by heart rate than are those of other myocardial cells (23,24), one would expect to observe postextrasystolic U waves after a long postextrasystolic pause. Indeed, we found that postextrasystolic U wave changes are facilitated by especially long pauses. These postextrasystolic U waves could then be markers for increased dispersion of refractoriness (between myocardial layers) in the postextrasystolic beat (30) and could potentially explain the association we observed between postextrasystolic U waves and a history of rapid ventricular arrhythmias. In our study, many of the postextrasystolic U wave changes were not recorded simultaneously in 12-lead ECGs. Therefore, we did not attempt to assess the magnitude of QT dispersion (between leads) in the postextrasystolic beat. In the only study looking at the dispersion of refractoriness of postextrasystolic beats (31), no differences were found between the QT dispersion of the beat before and that of the beat after a PVC. However, the patients in that study were free of heart disease and had neither spontaneous nor inducible ventricular arrhythmias. Also, the PVCs were paced rather than spontaneous, and only two coupling intervals were studied (31). The last limitation is of importance because 1) the action potential duration of a premature beat decreases in a steep biphasic fashion as the coupling interval decreases (26), and 2) PVCs with short coupling intervals have the greatest effects on the refractory periods of the postextrasystolic beat (27).

Another possible explanation for the observed association of postextrasystolic U waves after long pauses in patients with malignant ventricular arrhythmias could be related to the increased capability of the M cells to develop early after

depolarizations at slow heart rates (32). If sufficiently large, early afterdepolarizations may reach threshold potential and lead to triggered activity and tachyarrhythmias (32). We did not record the onset of sustained arrhythmias in our cohort. Therefore, we cannot elaborate on the importance of triggered activity in our study patients. Nevertheless, a recent report on a large number of sustained arrhythmias recorded during the Electrophysiologic Study Versus Electrocardiographic Monitoring (ESVEM) trial suggests that mechanisms other than reentry may play an important role in the onset of spontaneous arrhythmias in patients similar to those included in our study (33). Also, pause dependence is not restricted to torsade de pointes (34).

Limitations and clinical implications. We used the term postextrasystolic U wave augmentation to denote specific changes in the terminal part of the STU segment. It could be argued that changes involving the last positive deflection of biphasic or notched STU segments represent T wave rather than U wave changes (Fig. 3, B and C). Defining the end of the T wave and, thus, the onset of the U wave is problematic in all studies of the QT interval (35). We defined U wave changes as changes occurring after the peak of the T wave. This grading method was defined prospectively and the common denominator to our grade 3 score was the appearance of TU abnormalities after a PVC that resemble the TU abnormalities described for patients with the long QT syndrome during sinus rhythm (13,14). Thus, even if some of these postextrasystolic changes actually represent postextrasystolic "T wave humps," they still represent what is considered abnormal repolarization (13,14). Moreover, recent evidence (36) suggests that delayed repolarization of the M cells not only is responsible for the U waves, but also underlies the manifestation of notched T waves. Regardless of their actual terminology, terminal repolarization changes in the postextrasystolic beat were associated with a history of VT/VF in our study.

We did not measure the changes in the length of the QT interval after postextrasystolic pauses but, rather, quantitated the amplitude changes in the terminal repolarization waves. Many of the postextrasystolic U wave changes that we observed would not be included in the QT interval, which is generally defined as the interval from the onset of the R wave to the nadir between the T and the U wave (35). Moreover, some evidence suggests that the increment in U wave amplitude during sinus rhythm (37) or after a PVC (1,3,38), is a better marker for arrhythmic risk than is QT lengthening in patients with the pause-dependent long QT syndrome (1,3,37,38). Longer basic cycle lengths at the time of PVC recording correlated with postextrasystolic U wave augmentation. However, "basic heart rate" was not included in our multivariate analysis because not all patients had 24-h Holter ambulation ECG recordings, and there was no single baseline heart rate.

This was a retrospective study and the prevalence of ventricular arrhythmias in our study patients was high. Thus, the positive predictive value of postextrasystolic U wave augmentation would be artificially increased. Likelihood ratios are less dependent on prevalence and can be used to calculate the

predictive values of prognostic tests for populations with a known disease prevalence (16). For example, assuming that the incidence of sudden death is 2% for infarct survivors with a good LVEF and 10% for infarct survivors with a low LVEF (39), the positive predictive value of postextrasystolic U wave augmentation for predicting spontaneous arrhythmic events could be as high as 8% and 33%, respectively, for these patient groups. Prospective studies should be performed to confirm these predictive values, which compare favorably with those of other recognized predictive tests (39).

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