Isoproterenol Reversal of Antiarrhythmic Effects in Patients With Inducible Sustained Ventricular Tachyarrhythmias

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Seventeen patients (16 men and 1 woman) were challenged with isoproterenol after their initially inducible sustained ventricular tachyarrhythmia (monomorphic tachycardia in 14 patients and fibrillation in 3) was completely suppressed by class I antiarrhythmic drugs. Coronary artery disease was documented in 11 patients, dilated cardiomyopathy in 2 and no structural heart disease in the remaining 4 patients. The initial presentation was aborted sudden cardiac death (five patients), syncope (eight patients) and symptomatic nonsustained ventricular tachycardia (four patients). The antiarrhythmic drug that rendered the initial ventricular tachyarrhythmias noninducible was class IA in 11 cases, class IC in 5 and combined class IA and IB in 1.

The original ventricular tachyarrhythmia became inducible in 10 patients (group A) and remained noninducible in 7 patients (group B) after isoproterenol infusion at a rate necessary to achieve a 20% increase in heart rate. Despite the results of isoproterenol challenge, all patients were maintained on their electrophysiologically guided antiarrhythmic regimen. During a mean follow-up period of 12 ± 9 months, 3 of the 10 patients in group A experienced clinical recurrence of tachyarrhythmia; no recurrence was noted in group B.

In conclusion, reinducibility of ventricular tachyarrhythmia after beta-adrenergic stimulation seems to identify a subgroup of patients at high risk of subsequent arrhythmic events. Beta-adrenergic blockade or surgical therapy may be indicated in some patients with a positive isoproterenol challenge.

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Up to a 32% recurrence rate in the first 2 years of therapy has been reported (1) in patients treated with antiarrhythmic drugs that suppressed initiation of previously inducible sustained ventricular tachyarrhythmias. No convincing data exist to identify this subgroup of patients at high risk of subsequent arrhythmic events.

It has been previously shown (2-6) that beta-adrenergic stimulation can reverse suppressive antiarrhythmic drug effects on inducible supraventricular tachycardia. Furthermore, a higher clinical recurrence rate among these patients has been attributed to reversal of drug effects during high adrenergic states (3,4). A similar mechanism may be responsible for ventricular tachycardia recurrences in patients receiving electrophysiologically guided antiarrhythmic therapy.

To test this hypothesis the present study was undertaken to determine 1) the reversibility of various class I antiarrhythmic suppressive effects during isoproterenol infusion in patients with previously inducible sustained ventricular tachyarrhythmia, and 2) the usefulness of isoproterenol challenge in predicting subsequent clinical arrhythmic recurrences.

Methods

Study patients. Seventeen consecutive patients with inducible sustained ventricular arrhythmia that was subsequently controlled by antiarrhythmic drugs form the basis of this report. There were 16 men and 1 woman, aged 35 to 88 years (mean 60.8 ± 13.2). The indications for programmed ventricular stimulation included out-of-hospital sudden cardiac death (five patients), recurrent syncope due to sustained ventricular tachycardia (eight patients) and symptomatic nonsustained ventricular arrhythmia (four patients). Ten patients had coronary artery disease with previous myocardial infarction occurring at least 6 months before this study, and one patient had coronary artery disease without prior myocardial infarction. None of the patients with coronary artery disease had stable or unstable angina or evidence of...
ongoing ischemia. Two patients had dilated cardiomyopathy, and the remaining four had no clinical or laboratory evidence of structural heart disease.

**Electrophysiologic study.** Baseline electrophysiologic evaluation was performed in the patient with a nonsedated postabsorptive state after discontinuation of all antiarrhythmic drugs for at least 5 half-lives. The nature of the procedure was explained to all patients, and signed consent was obtained. With use of local anesthesia, three or more multipolar electrode catheters were inserted percutaneously through antecubital and femoral veins and positioned in the heart under fluoroscopic guidance. Intracardiac recordings were simultaneously displayed with surface electrocardiographic (ECG) leads (I, II, and V1) on a multichannel oscilloscope. These data were stored on magnetic tape and subsequently retrieved on photographic paper at speeds of 100 mm/s. Electrical stimulation was performed with a digital stimulator (Bloom Associates, Ltd.) at twice diastolic threshold.

The programmed ventricular stimulation protocol at baseline and during subsequent serial drug testing included the introduction of single, double and triple extrastimuli at several constant basic drive cycle lengths (400 to 600 ms) and up to double extrastimulation during abrupt cycle length changes (400 to 600 ms), as previously described (7). This pacing protocol was initially performed at the right ventricular apex, and subsequently repeated at the right ventricular outflow or inflow tract if no sustained ventricular arrhythmia was initiated. The induction of ventricular tachycardia was reproducible in all patients with sustained monomorphic tachycardia that was hemodynamically tolerated and could be terminated by overdrive pacing. In those patients whose arrhythmias resulted in hemodynamic compromise or required electrical cardioversion, the reproducibility of tachyarrhythmia induction was not assessed.

After completion of the stimulation protocol, patients with inducible sustained ventricular arrhythmia were treated with oral antiarrhythmic medications (single or in combination). Once a therapeutic steady state level was achieved, the efficacy of the regimen was evaluated within 1 h before the next scheduled dose (that is, during drug trough level). In those patients whose arrhythmias were still inducible, a second attempt at suppression was made. The site of induction was the right ventricular apex in 11 patients, right ventricular outflow tract in 4 patients and inflow tract in 2 patients. The site of induction was considered significant.

Assessment of cardiac function. Left ventricular wall motion and ejection fraction were determined in all patients by radionuclide angiography. Cardiac catheterization and coronary angiography were performed only in patients with an abnormal radionuclide angiogram.

**Definition of terms.** Ventricular tachycardia was considered to be sustained if it lasted >30 s or required prompt termination because of significant hemodynamic decompensation. Nonsustained ventricular tachycardia was defined as an arrhythmia lasting more than five consecutive complexes, but <30 s in duration. Antiarrhythmic therapy was considered successful if no ventricular tachyarrhythmia (sustained or nonsustained) could be induced.

**Statistical analysis.** Values are expressed as mean ± standard deviation. Wilcoxon analysis was performed for paired comparisons, and the Mann-Whitney U test was employed for unpaired data. A probability (p) value <0.05 was considered significant.

**Results**

The clinical and electrophysiologic characteristics of the 17 patients are outlined in Table 1.

**Baseline programmed ventricular stimulation.** Sustained monomorphic ventricular tachycardia was induced in 14 patients. The cycle length of tachycardia was 242 ± 40 ms (range 200 to 310). The number of extrastimuli required for tachycardia induction was one in four patients, two in four and three in six. Three additional patients had ventricular fibrillation induced during a single extrastimulus. The reproducibility of ventricular tachycardia induction could be assessed in 13 patients during baseline study. On the second attempt, the same number of extrastimuli were required in 11 patients (85%): more or fewer extrastimuli were needed in the remaining 2 patients, respectively. The site of induction was the right ventricular apex in 11 patients, right ventricular outflow tract in 4 patients and inflow tract in 2 patients.

**Evaluation of antiarrhythmic drug efficacy.** All patients underwent 1 to 6 (mean 1.8 ± 1.5) serial electrophysiologic drug trials until complete suppression of the inducible ventricular tachyarrhythmia was achieved. The final antiarrhythmic regimen associated with successful tachyarrhythmia suppression included quinidine in eight patients, proacainamide in one patient, disopyramide in one patient, encainide in four patients, flecainide in one patient, quinidine plus procainamide in one patient and quinidine plus mexiletine in one patient. As compared with the baseline study, the right ventricular effective refractory period during antiarrhythmic therapy was significantly longer (266 ± 22 ms, p < 0.001) at a cycle length of 400 ms.

**Assessment of isoproterenol on reversal of drug effects.** Ten patients (Cases 1 to 10, group A) demonstrated a reversal of antiarrhythmic effects as indicated by inducibility of the ventricular tachycardia. The right ventricular
Table 1. Clinical Data in 17 Patients

<table>
<thead>
<tr>
<th>Pt. No.</th>
<th>Age (yr) &amp; Gender</th>
<th>Heart Disease</th>
<th>Initial Presentation</th>
<th>Baseline Induced VT</th>
<th>Antiarrhythmic Drug Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pt. Age lyr)</td>
<td>Disease</td>
<td>Presentation</td>
<td>Morphology</td>
<td>Cycle Length (ms)</td>
</tr>
<tr>
<td>1</td>
<td>88M</td>
<td>CAD/MI</td>
<td>SCD</td>
<td>LBBB</td>
<td>210</td>
</tr>
<tr>
<td>2</td>
<td>69M</td>
<td>CAD/MI</td>
<td>SCD</td>
<td>RBBB</td>
<td>250</td>
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<tr>
<td>3</td>
<td>52M</td>
<td>None</td>
<td>Syncope</td>
<td>LBBB</td>
<td>220</td>
</tr>
<tr>
<td>4</td>
<td>53M</td>
<td>CAD</td>
<td>SCD</td>
<td>VF</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>76M</td>
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<td>Syncope</td>
<td>RBBB</td>
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<tr>
<td>6</td>
<td>35F</td>
<td>None</td>
<td>Syncope</td>
<td>RBBB</td>
<td>300</td>
</tr>
<tr>
<td>7</td>
<td>62M</td>
<td>CAD</td>
<td>SCD</td>
<td>RBBB</td>
<td>200</td>
</tr>
<tr>
<td>8</td>
<td>64M</td>
<td>CAD/MI</td>
<td>Palpitation</td>
<td>RBBB</td>
<td>220</td>
</tr>
<tr>
<td>9</td>
<td>63M</td>
<td>CM</td>
<td>Syncope</td>
<td>LBBB</td>
<td>255</td>
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<tr>
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<td>62M</td>
<td>CM</td>
<td>Syncope</td>
<td>RBBB</td>
<td>280</td>
</tr>
<tr>
<td>11</td>
<td>56M</td>
<td>CAD/MI</td>
<td>SCD</td>
<td>VF</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>59M</td>
<td>CAD/MI</td>
<td>Palpitation</td>
<td>RBBB</td>
<td>300</td>
</tr>
<tr>
<td>13</td>
<td>59M</td>
<td>CAD/MI</td>
<td>Syncope</td>
<td>VF</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>64M</td>
<td>CAD/MI</td>
<td>Syncope</td>
<td>RBBB</td>
<td>220</td>
</tr>
<tr>
<td>15</td>
<td>81M</td>
<td>CAD/MI</td>
<td>Syncope</td>
<td>RBBB</td>
<td>240</td>
</tr>
<tr>
<td>16</td>
<td>58M</td>
<td>None</td>
<td>Palpitation</td>
<td>LBBB</td>
<td>200</td>
</tr>
<tr>
<td>17</td>
<td>42M</td>
<td>None</td>
<td>Palpitation</td>
<td>RBBB</td>
<td>310</td>
</tr>
</tbody>
</table>

CAD = coronary artery disease; CM = cardiomyopathy; F = female; LBBB = left bundle branch block; M = male; MI = myocardial infarction; NA = not available; Pt. = patient; Q = every; RBBB = right bundle branch block; SCD = sudden cardiac death; VF = ventricular fibrillation; VT = ventricular tachyarrhythmia.

**Follow-up.** Patients in group A were followed up for 13 ± 6 months (range 10 to 28). At the time of hospital discharge, patients were treated in a manner tailored to their individual clinical circumstances as follows: six patients received the same antiarrhythmic regimen that resulted in complete suppression of their inducible ventricular tachyarrhythmia. Of these, two patients experienced clinical recurrence of ventricular tachycardia: one of these two patients (Case 2),

effective refractory period was significantly (p < 0.001) shortened from 265 ± 20 ms (preisoproterenol infusion) to 240 ± 28 ms (postinfusion). The mean cycle length of induced ventricular tachycardia was longer than the cycle length during baseline study (245 ± 43 and 235 ± 35 ms, respectively); however, the difference was not statistically significant (p > 0.1). As compared with baseline study, the morphology (that is, QRS configuration and frontal axis orientation) of the ventricular tachyarrhythmia remained unchanged in eight patients and was different in two; the site of induction was the same in eight patients and different in two; and the number of extrastimuli required for tachycardia induction remained the same in four patients, reduced in four and increased in two.

Isoproterenol infusion did not reverse the suppressive effect of the antiarrhythmic regimen in seven patients (Cases 11 to 17, group B), despite a significant shortening of the ventricular effective refractory period (from 262 ± 25 to 242 ± 20 ms, p < 0.001). A comparison of several variables between groups A and B did not reveal any significant statistical difference (Table 2). Patients receiving class IA and IC antiarrhythmic drugs were equally distributed in both groups. The mean sinus cycle length in groups A and B before isoproterenol infusion were 826 ± 132 and 840 ± 120 ms, respectively (p = NS), which shortened to 626 ± 97 and 665 ± 94 ms, respectively (p = NS) after isoproterenol challenge. Shortening of the sinus cycle length did not curtail the stimulation protocol.
while walking at a fast pace, experienced light-headedness that was quickly followed by frank syncope. He was taken to a local emergency room and found to have sustained ventricular tachycardia. He received an automatic implantable cardioverter-defibrillator (AICD) device and no antiarrhythmic therapy. The other patient (Case 9) experienced palpitation and light-headedness while becoming emotionally upset during an argument with a relative. These symptoms persisted and required medical attention. Subsequently, an ECG revealed sustained ventricular tachycardia, and a beta-adrenergic blocker was added to his original antiarrhythmic regimen. During a follow-up period of 10 months, he did not have any further recurrence.

On the basis of the results of isoproterenol infusion, the remaining four patients opted to have AICD implantation in addition to the antiarrhythmic drug therapy. In one of these patients (Case 7), the first AICD discharge occurred during sexual intercourse and was preceded by the same sensation of palpitation and light-headedness that he had previously experienced during documented ventricular tachycardia. The rate cutoff of his device was far above the maximal heart rate he had achieved during a treadmill exercise test. Subsequently, while he was being monitored on a continuous ambulatory ECG, he had two additional AICD discharges during strenuous physical activity, both discharges were appropriately delivered in response to spontaneous ventricular tachycardia. During a 12 month follow-up period, no further AICD discharges were noted after a beta-blocker was added to his regimen. Although the exact triggering mechanism could not be identified in these three patients (Cases 2, 7 and 9) with clinical recurrence of tachycardia, the circumstances surrounding these episodes were compatible with a high adrenergic state. In two of these three patients, analysis of blood drawn shortly after ventricular tachycardia recurrence revealed therapeutic serum drug levels. No evidence of electrolyte imbalance, acute myocardial ischemia or infarction could be detected in these patients shortly after their clinical events.

All patients in group B were discharged on the antiarrhythmic regimen that had led to complete suppression of their inducible ventricular tachyarrhythmia. During a follow-up period of 14 ± 4 months (range 10 to 18), no clinical recurrence was noted.

### Discussion

**Patients at high risk of tachycardia recurrence.** In patients with ventricular tachycardia, electrophysiologically guided antiarrhythmic therapy has been shown to be more efficacious than empirical therapy in preventing recurrence of a potentially lethal arrhythmia. Although initial investigations (9–11) suggested no subsequent arrhythmic events in this group of patients whose previously inducible ventricular tachycardia was suppressed by antiarrhythmic drugs, more recent studies have demonstrated the following substantial recurrence rates within the first 2 years of therapy: 17% to 32% in survivors of sudden cardiac death (1.12–14), 14% to 17% in patients with recurrent syncope due to sustained ventricular tachycardia (15–17) and 7% in patients with clinical nonsustained ventricular tachycardia (18). Because the recurrence of sustained ventricular tachyarrhythmia is a potentially fatal event, it seems crucially important to detect those patients at high risk of drug failure.

Among patients with different clinical presentations, those with out-of-hospital sudden cardiac death and recurrent syncope due to rapid ventricular tachycardia demonstrated a higher propensity for isoproterenol-induced antiarrhythmic reversibility (60% and 62.5%, respectively). This phenomenon was seen in only one of four patients who presented with symptomatic nonsustained ventricular tachycardia. Of particular interest, the three patients with a subsequent spontaneous arrhythmic event were among those initially presenting with sudden cardiac death (two patients) and syncope (one patient). The results of isoproterenol challenge influenced our decision concerning AICD implantation in patients whose ventricular tachyarrhythmias were rendered noninducible, particularly in those who initially presented with sudden cardiac death. Considering the high recurrence rate reported in this group of patients, AICD implantation seems a safer approach until more data are available.

**Mechanisms of action of beta-adrenergic stimulation.** The antiarrhythmic agents utilized in this study primarily consisted of class IA and IC drugs. These drugs are known to depress the fast inward sodium current and, as a result, slow the conduction velocity. Additionally, class IA drugs

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**Table 2. Different Cardiac and Electrophysiologic Variables for Groups A and B**

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean EF (%)</th>
<th>RVERP at 400 ms BD-CL (ms)</th>
<th>Decrease in Sinus CL With Iso (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>37</td>
<td>232 ± 17</td>
<td>265 ± 20</td>
</tr>
<tr>
<td>Group B</td>
<td>38</td>
<td>231 ± 18</td>
<td>262 ± 25</td>
</tr>
</tbody>
</table>

**Legend:** BD = basic drive; CL = cycle length; EF = ejection fraction; Iso = isoproterenol; NS = not significant; RVERP = right ventricular effective refractory period.
lengthen myocardial repolarization and, hence, the refractory period.

**Beta-adrenergic stimulation has been shown** (19) to have different effects on normal versus abnormal myocardium. In normal myocardial fibers, catecholamines have no effect on the resting potential, the rate of upstroke of the action potential (phase 0), membrane responsiveness or conduction velocity (20). In the presence of abnormal myocardial fibers with low resting membrane potentials, beta-adrenergic stimulation may lead to an increase in the rate of rise in phase 0 action potential amplitude and in conduction velocity, and could also shorten the refractory period (19). The mechanism by which isoproterenol infusion facilitates the initiation of ventricular tachycardia during programmed ventricular stimulation (21,22) could be related to these electrophysiologic effects or some other factors.

**Mechanism of reversal of antiarrhythmic drug effect by isoproterenol challenge.** The mechanism is not immediately apparent from the results of this study; however, some explanations may be offered. 1) Isoproterenol has been shown (23) to recruit functional calcium channels by means of activation of protein kinase, a process involving phosphorylation. In a similar manner, isoproterenol may augment the number of functional sodium channels (24), thus antagonizing the depressant action of antiarrhythmic agents. 2) Isoproterenol, like other beta-adrenergic stimulants, increases myocardial lactate production (25). This, in turn, may enhance the drug affinity to albumin by changing the regional plasma pH and, therefore, diminish the free drug level acting on the myocardium (26).

Although a comparable amount of isoproterenol was infused in both patient groups (as indicated by similar degree of shortening of sinus cycle length and the myocardial refractoriness), the original ventricular tachyarrhythmia became inducible only in group A patients. The reason for this disparity is not clear; however, the following points may have some relevance to this issue. First, a critical relation is required between the refractoriness and conduction velocity of the reentrant pathways for initiation and sustenance of the reentrant process. This delicate interaction is altered by effective antiarrhythmic drugs. Despite shortening of the refractory period after isoproterenol infusion, resumption of this critical relation may only occur in some cases. Second, dispersion of myocardial refractoriness probably has an arrhythmogenic role in some cases (27). It has been shown (28) that antiarrhythmic drugs decrease the dispersion of refractoriness. Isoproterenol challenge may restore the crucial degree of dispersion of refractoriness, but not necessarily in all cases. Third, in some patients, the effect of antiarrhythmic agents may be far more pronounced on the tissues surrounding the reentrant circuit as compared with that on the circuit itself (28). As a result of this drug-induced longer refractoriness of the encircling myocardium, a premature impulse (or impulses) cannot reach the reentrant circuit at critical coupling intervals necessary to initiate ventricular tachycardia. However, by removing this functional obstacle during beta-adrenergic stimulation, the inducibility of tachyarrhythmias could be resumed.

**Potential beneficial effect of beta-adrenergic blockade.** Beta-adrenergic blockade has been shown to be effective in suppressing clinical recurrent ventricular tachycardia when tachyarrhythmias are induced by exercise (29) or programmed ventricular stimulation during isoproterenol infusion (22). Aside from these distinct entities, however, addition of a beta-blocker to a class I agent for controlling ventricular tachyarrhythmias has been a controversial issue (30-36). Although addition of a beta-blocker in patients with a reversal of antiarrhythmic effects after isoproterenol infusion may be beneficial in some cases, the purpose of our study was to demonstrate the clinical relevance of the reversibility of antiarrhythmic effects induced by isoproterenol infusion before addition of a beta blocker was recommended. The potential beneficial effect of beta-blockers could be related to their several inherent properties: anti-ischemic effect, prolongation of myocardial refractoriness (37) and antagonization of high adrenergic states. The latter property seems the most likely mechanism controlling recurrent ventricular tachycardia in our patients (two patients in group A). Nevertheless, a larger number of patients and a longer follow-up duration are needed to support this hypothesis.

**Previous observations.** Several studies (2-6) have shown a 44% to 100% incidence of isoproterenol-induced reversal of antiarrhythmic effects in patients with supraventricular tachycardia. Furthermore, some of these investigations (3-6) reported a 40% to 60% clinical recurrence rate among treated patients with inducible tachycardia after isoproterenol infusion. In contrast, only 0 to 10% of the patients whose tachycardia had remained noninducible despite beta-adrenergic stimulation experienced clinical recurrences.

Morady et al. (38) recently reported epinephrine-induced reversal of quinidine effects in patients with ventricular tachycardia. The results of that study and the present one are in general agreement concerning the reversibility of the antiarrhythmic suppressive effects on inducible ventricular tachyarrhythmias during beta-adrenergic stimulation.

Nevertheless, our study provides additional important information as follows: 1) beta-adrenergic stimulation antagonized not only the antiarrhythmic effects of quinidine, but also those of other class I A agents (namely, procainamide and disopyramide) as well as those of class IC drugs (that is, encaïnine); and 2) tachyarrhythmias recurred only in patients with a positive isoproterenol challenge, further supporting the clinical relevance of this observation. Morady et al. (38) reported a 17% incidence rate (2 of 12 patients) of inducibility of ventricular tachycardia after epinephrine infusion in patients whose tachycardia had been completely suppressed. Ten (59%) of the 17 patients in our study demon-
strated this phenomenon after isoproterenol infusion. This disparity between the results of the two studies may be related to different patient groups, small sample size in both studies, a different degree of beta-adrenergic stimulation in the two studies or a combination of these factors.

**Limitations of the study.** One could argue that intrinsic variability of tachycardia induction over short periods may have been responsible for the reinducibility of ventricular tachyarrhythmia after isoproterenol infusion in group A. It has been previously shown (39) that, in patients with reproducible ventricular tachycardia induction (that is, patients requiring the same number of extrastimuli on the second induction attempt) during the control state, different numbers of extrastimuli may be required in 10% of the cases for ventricular tachycardia induction during subsequent drug testing. Because 85% of patients in the present study had induction of reproducible tachycardia on the second attempt during baseline study, it seems highly unlikely that intrinsic variability of induction would be the primary cause for the lack of ventricular tachycardia inducibility before isoproterenol infusion and reinducibility of tachycardia after this beta-adrenergic stimulation.

**Another potential area of concern may relate to serum antiarrhythmic levels at the time of drug testing:** specifically, could higher drug levels have prevented tachycardia induction after isoproterenol infusion in group A? The present study was not designed to address this concern; however, drug level by itself may not be sufficient to assess the adequacy of the medication being administered, and several other variables (such as degree of QRS lengthening, QT prolongation and increased ventricular myocardial refractoriness) should also be taken into consideration. For instance, patient 7 with a procainamide level of 6.0 µg/ml, which could be considered subtherapeutic, had a significant prolongation of the ventricular myocardial effective refractory period and QRS duration (40 and 35 ms, respectively).

**Conclusion.** Our results of this study indicate that 1) beta-adrenergic stimulation during isoproterenol infusion may reverse the antiarrhythmic effect of class I drugs and render tachycardia inducible, and 2) reinducibility of tachyarrhythmia after isoproterenol challenge may identify a subgroup of patients at higher risk of subsequent arrhythmic events.

Thus, it seems reasonable to consider beta-adrenergic stimulation as an adjunct to programmed ventricular stimulation to assess the reversibility of antiarrhythmic effects during a high adrenergic state. Addition of a beta-adrenergic blocker as adjunctive therapy may be justified in some patients with a positive beta-adrenergic stimulation challenge. Alternative approaches such as map-guided ablation of the ventricular tachycardia circuit or insertion of an automatic implantable cardioverter-defibrillator may offer better therapeutic options, particularly in survivors of sudden cardiac death.

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**References**


