Effect of Basic Drive Cycle Length on the Yield of Ventricular Tachycardia During Programmed Ventricular Stimulation

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The yield of sustained, monomorphic ventricular tachycardia (VT) induced by programmed ventricular stimulation was compared, using basic drive trains of 400 ms, 600 ms and sinus rhythm, to identify the most efficient sequence of basic drive trains to use during programmed stimulation. Fifty-five patients with coronary artery disease and inducible sustained monomorphic VT not requiring countershock to terminate underwent 81 electrophysiology tests in which 1 to 3 extrastimuli were introduced during sinus rhythm and after basic drive trains of 600 and 400 ms. In 72 electrophysiology tests, sustained, monomorphic VT was induced at the right ventricular apex. The yield of VT using a drive cycle length of 400 ms was 63 of 72 (88%), compared to 46 of 72 (64%) when the drive cycle length was 600 ms, and 23 of 72 (32%) when the extrastimuli were introduced during sinus rhythm ($p < 0.001$ for all pairwise comparisons). In 14 electrophysiology tests in which VT was not induced using a 400 ms basic drive cycle length at the apex, the yield of VT was higher using a 400 ms drive cycle length at a second right ventricular site (12 of 14) than with a 600 ms drive cycle length (3 of 12) or sinus rhythm (4 of 12) at the apex ($p < 0.05$). The yield of sustained, monomorphic VT induced by 1 to 3 extrastimuli increases as the basic drive cycle length shortens. Whereas programmed stimulation is conventionally started during sinus rhythm or with a drive cycle length of 600 ms, the present results suggest that starting with a drive cycle length of 400 ms may be more efficient.

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Programmed ventricular stimulation is conventionally performed by introducing extrastimuli during sinus rhythm and after basic drive trains of 400 to 600 ms.[1-11] When specified, programmed stimulation has been started during sinus rhythm or with a 600 ms basic drive cycle length.[1-11] However, a prior study demonstrated that the yield of ventricular tachycardia (VT) induced by a single extrastimulus increases as the basic drive cycle length is shortened,[12] suggesting that it may be more efficient to begin programmed stimulation using the shortest instead of the longest basic drive cycle length. To date, no studies have compared the yield of monomorphic VT induced by 1 to 3 extrastimuli using basic drive trains of 400 ms, 600 ms and sinus rhythm. To identify the most efficient sequence of basic drive trains to use during programmed ventricular stimulation, we compared the yield of sustained, monomorphic VT induced by programmed stimulation using basic drive trains of 400 ms, 600 ms and sinus rhythm.

METHODS

Patient characteristics: Our subjects were 55 patients with coronary artery disease and a history of sustained, monomorphic VT who had sustained monomorphic VT inducible by programmed ventricular stimulation and in whom the induced VT could be terminated by pacing. There were 47 men and 8 women, and the mean age was 63 ± 10 years (± standard deviation).

The study protocol was attempted in 145 electrophysiology tests; however, 64 cases were excluded because either sustained VT was not inducible (31), sustained, monomorphic VT requiring countershock to terminate was induced (29) or ventricular fibrillation or polymorphic VT requiring countershock to terminate was induced (4). The results of 81 electrophysiology tests were appropriate for analysis. Thirteen of the 81 electrophysiology tests were performed in the drug-free state, whereas 68 were performed in the presence of ≥1 class I antiarrhythmic drug (36), amiodarone (23) or amiodarone plus a class I drug (9).

Study protocol: Electrophysiology tests were performed in the fasting, nonsedated state after written, informed consent was obtained. Two quadripolar electrode catheters were positioned in the right ventricular apex and right ventricular outflow tract via a femoral vein. Additional electrode catheters were positioned in the high right atrium and His bundle position as clini-

TABLE I Sum of the Extrastimulus Coupling Intervals That Induced VT

Basic Drive Cycle Length*	No. of Extrastimuli That Induced VT		
	1	2	3
400 ms	297 ± 27	559 ± 66	768 ± 71
600 ms	300 ± 33	569 ± 74	782 ± 66
Sinus rhythm	290 ± 14	647 ± 85	835 ± 143
P value	>0.05	>0.05	>0.05

* Mean ± standard deviation (ms).
VT = ventricular tachycardia.

cally indicated. Electrocardiographic leads V_1, I and III and the intracardiac electrograms were recorded with a Siemens-Elema Mingograf-7 recorder. A programmable stimulator (Bloom Associates) was used for pacing. Pacing stimuli were 2 ms in duration and twice diastolic threshold.

Programmed stimulation was started at the right ventricular apex with 1, 2 and 3 extrastimuli using 8-beat basic drive trains at a cycle length of 400 ms. The technique used to scan diastole with the extrastimuli has been described previously.[9] To avoid the induction of nonclinical arrhythmias, coupling intervals were limited to 200 ms.[9] In all patients, the pacing protocol was then repeated using a drive cycle length of 600 ms and then during sinus rhythm. During sinus rhythm, the extrastimuli were introduced after every eighth sinus beat. The endpoint of stimulation at each basic drive cycle length was 1 induction of sustained, monomorphic VT or completion of stimulation with 1, 2 and 3 extrastimuli. If sustained, monomorphic VT was not induced using a drive cycle length of 400 ms at the right ventricular apex, the pacing protocol was repeated at the right ventricular outflow tract or septum in the same sequence used at the apex. Sustained VT was defined as VT lasting ≥30 seconds or requiring termination because of hemodynamic compromise. In accord with the selection criteria for subjects, sustained monomorphic VT was inducible in all subjects using this pacing protocol.

Data analysis: A weighted least squares analysis of categorical data using linear models was used to compare the yield of sustained, monomorphic VT between the basic drive cycle lengths.[13] To compare the percentage of patients at each drive cycle length requiring 3 extrastimuli to induce VT, maximum likelihood contingency table analysis was used.[14] Analysis of variance was used to compare the sum of the coupling intervals that induced VT between the different drive cycle lengths. A p value <0.05 was considered statistically significant.

RESULTS

Effect of the drive cycle length on yield of induced ventricular tachycardia: In 72 electrophysiology tests, sustained, monomorphic VT was induced by programmed stimulation at the right ventricular apex. The yield of VT using a drive cycle length of 400 ms was 63 of 72 (88%), compared to 46 of 72 (64%) when the drive cycle length was 600 ms, and 23 of 72 (32%) when the extrastimuli were introduced during sinus rhythm (mean sinus cycle length 840 ± 154 ms; p <0.001 for all pairwise comparisons).

In 28 of the 72 electrophysiology tests, VT was inducible by programmed stimulation using only 1 of the drive cycle lengths. Among these 28 cases, significantly more were inducible only with a drive cycle length of 400 ms (21 of 28) than with a drive cycle length of 600 ms (4 of 28, p <0.001) or during sinus rhythm (3 of 28, p <0.001).

In 44 of the 72 electrophysiology tests, sustained, monomorphic VT was induced using >1 drive cycle length. In 28 of these 44 tests (64%), the VT induced with the different drive cycle lengths had the same configuration; in 16 cases, the monomorphic VTs induced with the different drive cycle lengths had different configurations.

There was no significant difference in the number of episodes of VT requiring 3 extrastimuli to induce with the 400 ms drive cycle length (35%) compared with the 600 ms drive cycle length (41%). However, a greater percentage of episodes of VT induced during sinus rhythm (74%) required 3 extrastimuli to induce as compared to when the drive cycle length was 400 or 600 ms (p <0.01).

Comparison of coupling intervals that induced ventricular tachycardia: To determine whether the different yields of induced VT with the various drive cycle lengths was attributable to a difference in the coupling intervals used to induce VT, the sums of the coupling intervals used to induce VT with 1, 2 or 3 extrastimuli were compared (Table I). There were no significant differences between the 400 or 600 ms drive cycle lengths or sinus rhythm.

Yield of ventricular tachycardia at the second right ventricular site: In only 18 of the 81 electrophysiology tests was sustained, monomorphic VT not inducible using a drive cycle length of 400 ms at the right ventricular apex. In 14 of these tests, the pacing protocol was completed both at the right ventricular apex and at the right ventricular outflow tract or septum with a drive cycle length of 400 ms. The yield of sustained monomorphic VT was significantly higher with a 400-ms drive cycle length at the second right ventricular site (12 of 14) than with a 600-ms drive cycle length (3 of 12) or sinus rhythm (4 of 12) at the apex (p <0.05).

Cycle length of induced ventricular tachycardia: There were no significant differences among the mean cycle lengths of the VTs induced using a drive cycle length of 400 ms (377 ± 78 ms), 600 ms (381 ± 80 ms) or sinus rhythm (402 ± 82 ms).

Yield of nonclinical arrhythmias: Four electrophysiology tests were excluded from this study because sustained polymorphic VT or ventricular fibrillation was induced. One of these nonclinical arrhythmias was induced by 1 extrastimulus, 2 were induced by 2 extrastimuli and 1 by 3 extrastimuli. All were induced using

a drive cycle length of 400 ms, which was the first drive cycle length used.

DISCUSSION

Major findings: In our study, basic drive cycle lengths of 400 ms, 600 ms and sinus rhythm were compared because these are the drive cycle lengths that are conventionally used during clinical electrophysiology tests. The results of our study demonstrate that there is a significant increase in the yield of sustained, monomorphic VT as the basic drive cycle length is shortened. By starting programmed stimulation using a drive cycle length of 400 ms, sustained monomorphic VT was induced in 88% of patients with VT inducible at the right ventricular apex with 1 to 3 extrastimuli. In contrast, using a drive cycle length of 600 ms or sinus rhythm, the yield of sustained, monomorphic VT was only 64 and 32%, respectively. When VT was not induced using a drive cycle length of 400 ms at the right ventricular apex, the yield of sustained, monomorphic VT was substantially higher using a drive cycle length of 400 ms at a second right ventricular site compared to continuing with programmed stimulation at the right ventricular apex using a drive cycle length of 600 ms or sinus rhythm.

Whereas programmed ventricular stimulation is conventionally started during sinus rhythm or with a drive cycle length of 600 ms,[1-11] our results suggest that it may be more efficient to start with a drive cycle length of 400 ms. This is particularly relevant to patients who are undergoing an electrophysiology test for the purpose of evaluating antiarrhythmic drug efficacy. In these patients, the first induced episode of sustained, monomorphic VT may be sufficient to demonstrate drug inefficacy and may serve as an adequate endpoint for stimulation. If VT is not induced by programmed stimulation with 1 to 3 extrastimuli at the right ventricular apex, it would be more efficient to repeat programmed stimulation with 1 to 3 extrastimuli at a second right ventricular site instead of using longer basic drive cycle lengths at the apex.

Possible mechanisms: Because the ventricular effective refractory period decreases as the basic drive cycle length is shortened,[15] a possible mechanism accounting for the higher yield of sustained, monomorphic VT with the use of a 400-ms drive cycle length is that shorter extrastimulus coupling intervals were achieved than with the use of a 600-ms drive cycle length or during sinus rhythm. However, no significant difference in the sum of the coupling intervals that induced VT was found among the episodes of VT induced with the same number of extrastimuli using a drive cycle length of 400 ms, 600 ms or sinus rhythm. This suggests that the higher yield of VT with the 400-ms drive cycle length is not attributable to the use of shorter extrastimulus coupling intervals. Similarly, prior studies also have found that the facilitation of VT induction at shorter drive cycle lengths is not explained solely by achievement of shorter coupling intervals.[12,16]

The basic drive is likely to influence the electrophysiologic properties of the VT reentry circuit and of the surrounding myocardium, and therefore it is possible that the yield of VT was highest with the 400-ms drive cycle length because of a direct effect of the shorter drive cycle length on refractoriness, conduction within the reentry circuit, intervening myocardium or a combination.[17]

Specificity of programmed stimulation: The use of 3 extrastimuli has been demonstrated to increase the sensitivity of programmed ventricular stimulation compared to the use of 1 or 2 extrastimuli.[3-5] On the other hand, the use of 3 extrastimuli may also impair the specificity of programmed stimulation by resulting in the induction of nonclinical forms of polymorphic VT and ventricular fibrillation.[4,5] However, with limitation of the extrastimulus coupling intervals to 200 ms, sustained polymorphic VT or ventricular fibrillation was induced in only 4 of the 145 electrophysiology tests in which the study protocol was attempted. Therefore, our results demonstrate that the early use of 3 extrastimuli in a stimulation protocol need not necessarily impair the specificity of programmed ventricular stimulation.

Limitations: Because our study design required multiple attempts at the induction of VT, only patients who had VT that could be terminated with pacing were included. Therefore, our results may not apply to patients who have hemodynamically unstable VT or VT requiring countershock to terminate.

A second possible limitation is that a high percentage of the patients (84%) were being treated with antiarrhythmic drugs at the time of electrophysiologic testing. The possibility that the antiarrhythmic drugs influenced the relative yield of VT with the various basic drive cycle lengths tested cannot be ruled out.

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