Paroxysmal Supraventricular Tachycardia in Patients with Mitral Valve Prolapse

MARK E. JOSEPHSON, M.D., LEONARD N. HOROWITZ, M.D., AND JOHN A. KASTOR, M.D.

SUMMARY The mechanism of supraventricular tachycardia was evaluated in twelve patients with mitral valve prolapse utilizing standard intracardiac recording and stimulation techniques. Eight patients had normal electrocardiograms, three had a short PR interval and normal QRS (Lown-Ganong-Levine syndrome) and one had Wolff-Parkinson-White type A. Six of the eight patients with normal electrocardiograms were demonstrated to have atrioventricular bypass tracts. Five patients had A-V nodal re-entrant supraventricular tachycardia. In two patients the bypass tract could be demonstrated to conduct antegradely when the left atrium was paced via the coronary sinus, while in four the bypass tract only conducted retrogradely. In all seven patients with atrioventricular bypass tracts, the accessory pathway was left-sided. We conclude that a) supraventricular tachycardia in the mitral valve prolapse syndrome appears related to a high frequency of bypass tracts; b) electrophysiological studies are required to diagnose these bypass tracts; and c) the atrioventricular bypass tracts may be related to the mitral valve abnormality since they are always left-sided.

MITRAL VALVE PROLAPSE has become recognized as the most prevalent cardiac valvular abnormality, affecting perhaps 6% of the population.2-5 Arrhythmias are an important complication of this disorder. While ventricular premature depolarizations are most frequently noted, paroxysmal supraventricular tachycardia is probably the most commonly sustained tachyarrhythmia.6,7 The present study was undertaken to analyze the mechanisms of supraventricular tachycardia that occur with mitral valve prolapse and compare them to the mechanisms that are responsible for supraventricular tachycardias in the population at large.

Methods and Material

Electrophysiologic studies were performed in twelve patients with auscultatory and/or echocardiographic findings of mitral valve prolapse in whom paroxysmal supraventricular tachycardia had been documented (table 1). There were seven women and five men, aged from 17 to 63 years. Their resting electrocardiograms demonstrated a short PR interval (≤.12 sec) with a normal QRS in three, Wolff-Parkinson-White type A in one, and normal in the remaining eight.

Each patient was studied in the postabsorptive nonsedated state after informed consent was obtained. Antiarrhythmic agents were discontinued 48 hours prior to study. Quadripolar electrode catheters were percutaneously inserted through the femoral and/or antecubital veins and positioned under fluoroscopic control in the right atrium, right ventricle, and coronary sinus. One pair of electrodes was used for recording and the other for stimulation. A tripolar catheter was percutaneously introduced through the right femoral vein and positioned across the tricuspid valve to obtain a His bundle electrogram. The intracardiac electrograms were simultaneously recorded with multiple surface electrocardiographic leads, usually I, aVF, and V1, and displayed on a switch-beam oscilloscope (E for M, DR16).

In each patient the mechanism of the tachycardia was determined using intracardiac recordings and analyzing the response to atrial and ventricular pacing and extrastimuli delivered by a custom designed programmable stimulator using an optically isolated constant current source (Bloom Associates). Particular attention was paid to the mode of initiation of supraventricular tachycardia, the atrial activation sequence during the tachycardia, the effects of developing bundle branch block during the tachycardia, and the effects of stimulation (atrial and ventricular) during the tachycardia.

The mechanisms suggested by the electrocardiographic findings included: a) A-V nodal re-entry;4,9 b) A-V nodal re-entry associated with the Lown-Ganong-Levine syndrome;4,10 and c) atrio-nodal-ventriculo-atrial circus movement re-entry characteristic of the Wolff-Parkinson-White syndrome.4,12-16 Criteria used to define these mechanisms were as follows:

Re-entry Within the A-V Node
1. Dual A-V nodal pathways.
2. Echo zone and initiation of supraventricular tachycardia dependent upon attaining a critical A-H interval.
3. Normal retrograde atrial activation during supraventricular tachycardia.
4. Recording of retrograde atrial electrogram prior to or simultaneous with the onset of the QRS.

Atrio-Nodal-Ventriculo-Atrial Re-entry (Wolff-Parkinson-White Syndrome)
1. Supraventricular tachycardia dependent on critical A-V interval only after antegrade block in bypass tract.
2. Eccentric retrograde atrial activation sequence during supraventricular tachycardia.
3. Ability to pre-excite the atrium with ventricular premature depolarizations during supraventricular tachycardia at a time when the bundle of His is either refractory or participating in antegrade conduction.
4. Prolongation of ventriculo-atrial conduction with the development of functional bundle branch block during supraventricular tachycardia.

Results
A-V Nodal Re-entry
Two patients demonstrated typical A-V nodal re-entry. The spontaneous occurrence of paroxysmal supraventricular
Atrio-Nodal-Ventriculo-Atrial Re-entry

dual A-V with prolongation is normal. A with a patient in beats/min. conduction through the during sequence to or or,Seven patients (cases 3, 4, 5) demonstrated the short PR, normal QRS, abbreviated A-V nodal conduction time, and blunted A-V nodal response to atrial pacing characteristic of the Lown-Ganong-Levine syndrome. The tachycardia rates in these patients were 150, 162 and 200 beats/min. A-H intervals in these patients were 50–55 msec and all showed less A-H prolongation in response to rapid atrial pacing than normal. A dual pathway response was demonstrated in each patient with the tachycardia occurring during slow pathway conduction through the A-V node. The atrial activation sequence during the tachycardia was identical to that seen in typical A-V nodal re-entry and atrial activation appeared prior to or at the onset of ventricular depolarization.

Atrio-Nodal-Ventriculo-Atrial Re-entry

Seven patients demonstrated an atrioventricular bypass tract participating in the tachycardia. The bypass tract was manifest in the one patient who demonstrated a Wolff-Parkinson-White type A pattern on the electrocardiogram. In two patients the bypass tract was latent, with the characteristic delta wave and bizarre QRS brought out by coronary sinus pacing (fig. 2). The supraventricular tachycardia in the three patients with manifest or latent pre-excitation was demonstrated to incorporate the accessory pathway in the re-entrant circuit. In four patients (cases 9–12) an atrioventricular bypass tract was concealed during antegrade stimulation studies, but was shown to be operative during supraventricular tachycardia by a) eccentric retrograde atrial activation during the tachycardia (fig. 3); b) prolongation of ventriculo-atrial conduction with the development of left bundle branch block (fig. 4); and c) the ability to prematurely depolarize the atria with ventricular stimulation during the tachycardia (fig. 5). The tachycardia rates ranged from 170–230 beats/min in this group. In the two patients with the fastest rate of supraventricular tachycardia (230/min) the bypass tract was not manifest on the surface electrocardiogram (cases 8 and 11). In all cases with a functioning atrioventricular bypass tract, the location was demonstrated to be left-sided by a retrograde atrial activation pattern with the earliest activation in the left atrium.

Atrio-Ventriculo-Atrial Re-entry

Three patients (cases 3, 4, 5) demonstrated the short PR, normal QRS, abbreviated A-V nodal conduction time, and blunted A-V nodal response to atrial pacing characteristic of the Lown-Ganong-Levine syndrome. The tachycardia rates in these patients were 150, 162 and 200 beats/min. A-H intervals in these patients were 50–55 msec and all showed less A-H prolongation in response to rapid atrial pacing than normal. A dual pathway response was demonstrated in each patient with the tachycardia occurring during slow pathway conduction through the A-V node. The atrial activation sequence during the tachycardia was identical to that seen in typical A-V nodal re-entry and atrial activation appeared prior to or at the onset of ventricular depolarization.

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![Figure 1](http://circ.ahajournals.org/)

**Figure 1.** Spontaneous A-V nodal re-entrant supraventricular tachycardia (patient 1). The panel is organized from top to bottom: surface ECG leads I, aVR, V, a right high atrial electrocardiogram (HRA), coronary sinus electrogram (CS), His bundle electrogram (HBE) and time lines (T). Subsequent intracardiac records are similarly organized. The first two beats are sinus with a normal AH 80 msec. The third beat is an atrial premature depolarization which results in AH prolongation and the development of supraventricular tachycardia. Note during supraventricular tachycardia, atrial activation is earliest in the HBE and begins prior to the inscription of the QRS, a diagnostic feature of A-V nodal re-entrant supraventricular tachycardia.

<table>
<thead>
<tr>
<th>Patient/Sex/Age</th>
<th>ECG</th>
<th>Rate of SVT (beats/min)</th>
<th>Clinical findings</th>
<th>Echo findings</th>
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<tr>
<td>1/M/48</td>
<td>NL</td>
<td>200</td>
<td>MSC, LSM</td>
<td>PLP and ALP</td>
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<td>2/F /17</td>
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<td>150</td>
<td>Mult. MSC, LSM</td>
<td>PLP and ALP</td>
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<td>LSM</td>
<td>PLP</td>
</tr>
<tr>
<td>4/F /28</td>
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<td>150</td>
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<tr>
<td>5/F /37</td>
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<td>162</td>
<td>MSC, LSM</td>
<td>PLP and ALP</td>
</tr>
<tr>
<td>6/F /53</td>
<td>WPW A</td>
<td>180</td>
<td>LSM</td>
<td>PLP</td>
</tr>
<tr>
<td>7/M/35</td>
<td>1° AVB, IVC, LAH</td>
<td>200</td>
<td>early nonejection click, long systolic murmur</td>
<td>holosystolic PLP and ALP, with diastolic fluttering</td>
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<tr>
<td>8/F /28</td>
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<td>230</td>
<td>Mult. MSC, LSM</td>
<td>PLP</td>
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<td>170</td>
<td>MSC, LSM</td>
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<tr>
<td>12/M/39</td>
<td>NL</td>
<td>200</td>
<td>LSM</td>
<td>PLP and ALP</td>
</tr>
</tbody>
</table>

**Abbreviations:** ALP = anterior leaflet prolapse; AVB = atrio-ventricular block; IMI = inferior myocardial infarction; IVC = intraventricular conduction defect; LSM = late systolic murmur; MSC = mid-systolic click; NL = normal; PLP = posterior leaflet prolapse; Mult. = multiple.

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**Table 1. Patient Data**
as recorded in the coronary sinus electrogram. Further support of a left-sided bypass tract was the development of prolongation of ventriculo-atrial conduction and cycle length with the development of left bundle branch block in three patients. In none of our patients with bypass tracts was A-V nodal re-entry present.16,17

Discussion

Paroxysmal supraventricular tachycardia is probably the most common sustained tachyarrhythmia in patients with the mitral valve prolapse syndrome.1,9

The surface electrocardiograms were misleading regarding the mechanism of supraventricular tachycardia in that eight of our twelve patients demonstrated no abnormalities suggestive of pre-excitation. Detailed electrophysiologic evaluation demonstrated that only five patients had A-V nodal re-entrant supraventricular tachycardia. In each of these patients a bypass tract in any location, free wall or septal, was excluded by the recording of retrograde atrial activation prior to the ventricular electrogram (fig. 1). In seven

an atrioventricular accessory pathway formed one limb of the re-entrant circuit.

Of the seven patients with atrioventricular bypass tracts only one had electrocardiographic evidence of the Wolff-Parkinson-White syndrome. In two, antegrade pre-excitation was only manifest during atrial pacing and was much more evident when the left atrium (via the coronary sinus) was paced.12,14,16 Of great interest was the absence of any evidence of antegrade pre-excitation in the remaining four patients with atrioventricular bypass tracts. In these patients the accessory pathway was concealed during antegrade stimulation studies.12-14 The participation of these bypass tracts in the supraventricular tachycardia was demonstrated by a) eccentric retrograde atrial activation; b) the ability of a ventricular premature depolarization to pre-excite the atrium during the tachycardia; and c) prolongation of ventriculo-atrial conduction time with the development of left bundle branch block.

In all patients with atrioventricular bypass tracts, the accessory pathway was left-sided. This is intriguing in the light of the known abnormalities of the mitral apparatus.
Gallagher also found only left-sided bypass tracts in seven patients with mitral prolapse and the Wolff-Parkinson-White syndrome. This situation is analogous to Ebstein's anomaly of the tricuspid valve which, when associated with an atrioventricular bypass, is always associated with a type B Wolff-Parkinson-White pattern which is due to a rightsided atrioventricular bypass tract. In both instances the developmental abnormality giving rise to the valvular malformation may be related to the associated electrophysiologic findings.

Significance of Results

In 60% of our patients some form of pre-excitation was present. Since a rational approach to therapy of arrhythmias is predicated on the understanding of their underlying mechanisms, it is obviously important that patients with mitral valve prolapse and supraventricular tachycardia be evaluated for the presence of bypass tracts before therapeutic interventions are begun. Drugs such as digoxin and propranolol that may be extremely useful in either A-V nodal re-entrant tachycardia or circus-movement re-entry using an atrioventricular bypass tract, may be dangerous in the presence of antegrade conduction over an atrioventricular bypass tract. Should any of these patients also have atrial fibrillation or atrial flutter with rapid antegrade conduction over the accessory pathway, digitalis may facilitate conduction over the bypass tract and lead to ventricular fibrillation. The absence of electrocardiographic evidence of the Wolff-Parkinson-White syndrome should not be taken as evidence that such an event could not occur. Three months prior to study, case 7, who only demonstrated evidence of pre-excitation with coronary sinus pacing, had an episode of ventricular flutter-fibrillation induced by a bunt of atrial flutter-fibrillation with rapid conduction down his accessory pathway in the presence of digitalis. This mechanism may be responsible for some episodes of sudden death in this syndrome.

Relationship to Common Mechanisms of Supraventricular Tachycardia in the General Population

The incidence of bypass tracts participating in supraventricular tachycardia associated with mitral valve prolapse is inordinately high. In our experience, A-V nodal re-entry is the mechanism in two-thirds of the episodes of paroxysmal supraventricular tachycardia in the general population while bypass tracts are operative in only 20% of cases. Wu and Akhtar (unpublished data) have similar findings. This increased frequency of bypass tracts should be taken into consideration when therapy is required or has failed previously. Electrophysiologic investigation should probably be undertaken in such patients.

References

ventricular asynergy in the prolapsing mitral leaflet syndrome. Am J Cardiol 29: 611, 1972

**Efficacy of Propranolol in the Control of Exercise-Induced or Augmented Ventricular Ectopic Activity**

J. V. NIXON, M.D., WEEMS PENNINGTON, M.D., WILLIAM RITTER, M.D., AND WILLIAM SHAPIRO, M.D.

**SUMMARY**
The effect of propranolol on exercise-induced or augmented ventricular ectopy was studied in sixteen male patients, six of whom had documented coronary artery disease. Fifteen patients were exercised after two weeks of oral therapy, four after single oral therapy and eight patients after intravenous therapy. Propranolol dosage was titrated to produce maximal beta-adrenergic blockade.

Effective reduction of exercise-induced ventricular ectopy occurred in ten of fifteen patients ($P < 0.001$), and in five of six patients with coronary disease ($P < 0.02$). Propranolol therapy abolished ventricular couplets in eight of twelve patients and ventricular tachycardia in four of five patients. Single oral and intravenous therapy had similar or greater effects. Plasma propranolol levels following different routes of administration did not correlate with exercise-induced maximal heart rates or percent reduction in ventricular ectopy. When compared to exercise in eleven patients, ambulatory monitoring underestimated the severity, particularly the highest grades, of ventricular ectopy.

It is generally accepted that ventricular ectopic activity in the presence of ischemic heart disease requires therapeutic control because of its association with a high incidence of sudden cardiac death. However, the selection of a suitable antiarrhythmic agent has become a cause of much concern for reasons of either demonstrated inefficacy or a higher than acceptable incidence of therapeutic side effects. Furthermore, methods for the detection of ventricular ectopic activity have come under close scrutiny recently. The suggestion that both stress testing and prolonged ambulatory monitoring are necessary, not only for the demonstration of ventricular ectopic activity but also for the evaluation of the efficacy of antiarrhythmic therapy, requires further confirmation.

Although propranolol is known to be effective in the control of ventricular ectopic activity at rest, and the plasma levels required for the suppression of ventricular ectopic activity observed at rest have been documented, only individual cases of the utilization of propranolol in exercise-induced ventricular ectopic activity have been reported.

The purpose of this study was to determine the effect of propranolol on exercise-induced or augmented ventricular ectopic activity, and to compare the plasma propranolol levels required for the suppression of ectopic activity during exercise with those previously reported to be effective in patients at rest. The relative value of brief periods of continuous ambulatory monitoring were compared with stress testing as a means of evaluating ventricular ectopic activity in patients before and after the administration of propranolol.

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