Accessory Atrioventricular Pathways That Conduct Only in the Antegrade Direction

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SUMMARY Patients with accessory atrioventricular pathways that conduct only in the antegrade direction represent an unusual variant of the Wolff-Parkinson-White syndrome. This report describes such patients and compares them with patients with accessory pathways that demonstrate bidirectional conduction.

Of 143 patients with single accessory pathways, seven demonstrated exclusive antegrade conduction (study group), 111 demonstrated bidirectional conduction (control group), and 25 demonstrated exclusive retrograde conduction. Study group patients were significantly older than patients in the control group (42 ± 9.8 years and 31.4 ± 13.9 years, respectively, p < 0.0001). Refractoriness and conduction characteristics of the accessory pathways in the antegrade direction in the study group were not different from those in the control group. Control group patients presented with atrioventricular reentrant tachycardia (58 of 111), atrial fibrillation (23 of 111), both of these arrhythmias (19 of 111), or no documented arrhythmia (11 of 111). Study group patients presented with only atrial fibrillation (six of seven).

An accessory pathway with only antegrade conduction is a rare cause of symptoms in the Wolff-Parkinson-White syndrome. These patients are asymptomatic until atrial fibrillation develops as the patient ages. Despite the absence of retrograde conduction over the accessory pathway, its antegrade functional properties are similar to pathways that demonstrate bidirectional conduction.

PATIENTS with accessory atrioventricular (AV) pathways often present with electrocardiographic abnormalities or cardiac arrhythmias. An accessory pathway conducting in the antegrade direction causes a delta wave in the QRS complex during sinus rhythm and may conduct impulses to the ventricle during atrial fibrillation or atrial flutter. An accessory pathway conducting only in the retrograde direction causes no electrocardiographic abnormalities during sinus rhythm but may conduct impulses in the retrograde direction during AV reentrant tachycardia. Accessory pathways that conduct in both the antegrade and retrograde direction and pathways that conduct exclusively in the retrograde direction have been studied extensively. In contrast, very little is known about accessory pathways that conduct only in the antegrade direction. This report reviews the clinical characteristics and the electrophysiologic properties of accessory pathways in patients whose accessory pathways conduct only in the antegrade direction.

Methods

Patient Population

Patients included in this study were referred to the Division of Cardiology at Duke University and evaluated in the Clinical Electrophysiology Laboratory between December 1974 and January 1979. Seven patients who had accessory pathways demonstrating conduction only in the antegrade direction were identified by reviewing reports of electrophysiologic studies performed during that time. These seven patients are the basis of this report.

Clinical Evaluation

The seven patients underwent a history and physical examination, chest x-ray and ECG. Documentation of all spontaneous arrhythmias recorded before our study was sought from referring physicians. Only one patient had not exhibited a sustained spontaneous arrhythmia. This patient had a history of palpitations and presyncope. Because of her extreme anxiety about the importance of these symptoms, an electrophysiologic study was done.

Electrophysiologic Evaluation

Medications were discontinued 48 hours before the electrophysiologic study. Patients were evaluated in the postabsorptive state and were lightly sedated with diazepam if necessary. The method of electrophysiologic study has been described.

We recognized in 1976 that catheter manipulation during the electrophysiologic study could result in temporary inability of an accessory pathway to conduct impulses. Three of our patients were studied after that discovery, and we suspected before the electrophysiologic study that all three had absent retro-
grade conduction because reentrant tachycardia had not been documented. Consequently, their studies were done with particular attention to decreasing catheter manipulation. One catheter was passed to the right ventricular apex and a second catheter to the junction of the right atrium and superior vena cava. Right ventricular pacing was then performed to assess ventriculoatrial conduction. The study was then completed as previously described.

Conduction over the accessory pathway was evaluated by incremental pacing from two or more atrial sites, by the extrastimulus technique, and by measuring the rate of AV conduction after elective induction of atrial fibrillation, if this was not observed during the study.

Retrograde conduction was evaluated by incremental pacing from the apex of the right ventricle. If ventriculoatrial conduction was present, conduction in the retrograde direction was assessed with incremental pacing and the extrastimulus technique.

Localization of the accessory pathway in patients with accessory pathways that had conduction only in the antegrade direction was determined by analyzing the mean vector of the first 40 msec of the delta wave as recorded by the 12-lead ECG during maximal pre-excitation. This method of accessory pathway localization has been verified by epicardial mapping and results of surgical incision of pathways.13

Criteria for Inclusion in the Study Group

Conduction over an accessory pathway in the antegrade direction was present if two criteria were met: the delta wave was present in sinus rhythm and after incremental atrial pacing, and the AH interval was prolonged and the His deflection moved further into the QRS complex during incremental atrial pacing.

Conduction over an accessory pathway in the retrograde direction was considered absent if complete AV dissociation was present with all cycle lengths of ventricular pacing and there was no history of reentrant tachycardia. If ventriculoatrial conduction was present during ventricular pacing, this conduction used the AV node if (1) during measurement of the ventricular refractory period a retrograde His bundle electrogram was recorded and preceded atrial activation; (2) atrial activation during ventricular pacing began at the septum and proceeded laterally in a symmetric pattern; (3) the sequence of atrial activation after premature ventricular complexes was the same at all coupling intervals and identical to the sequence recorded during the basic drive; and (4) the sequence of atrial activation on successive beats during second-degree ventriculoatrial block induced by incremental ventricular pacing was the same and identical to the sequence recorded during 1:1 ventriculoatrial conduction.

Criteria for Inclusion in the Control Group13

Patients in the control group were studied during the same period as patients with accessory pathways that could conduct only in the antegrade direction. Patients in the control group had single accessory AV pathways that demonstrated both antegrade and retrograde conduction. An accessory AV pathway conducted in the retrograde direction if (1) eccentric activation of the atrium during reciprocating tachycardia or right ventricular pacing, (2) premature ventricular depolarizations introduced during reciprocating tachycardia preexcited the atrium at a time when the His bundle was refractory with the same atrial activation sequence as during reciprocating tachycardia, or (3) ventriculoatrial conduction during reciprocating tachycardia was prolonged during bundle branch block.

Patients were excluded from the control group if they had (1) accessory pathways capable of conducting only in the retrograde direction, (2) multiple accessory pathways, or (3) Mahaim fibers.

Operative Methods

The technique of epicardial mapping14 and operative division of accessory pathways15 has been described.

Statistical Methods

The following variables were compared using the t test: age, antegrade refractory period of the accessory pathway, shortest cycle length with 1:1 antegrade conduction over the accessory pathway, mean RR interval during atrial fibrillation, and shortest RR interval between two preexcited beats during atrial fibrillation. A method for comparing groups of unequal variances and sample sizes was used. The following variables were analyzed using the chi-square statistic: associated cardiovascular disease, type of spontaneous arrhythmia observed before study and accessory pathway location.

Results

Prevalence of Accessory Pathways That Conduct Only in the Antegrade Direction

Between December 1974 and January 1979, 143 patients with single AV accessory pathways and symptomatic arrhythmias were studied. Seven (5%) of these patients had accessory pathways that conducted only in the antegrade direction, and these seven patients are the study group. An additional 111 (78%) patients had pathways with bidirectional conduction, and these patients are the control group. The remaining 25 (17%) patients had pathways with conduction in only the retrograde direction.

Clinical Evaluation

Patients with accessory pathways that conducted only in the antegrade direction were significantly older (mean 42.0 ± 9.8 years) than patients in the control group (mean 31.4 ± 13.9 years) (p < 0.0001). Atrial fibrillation was the only presenting arrhythmia in the study group and was documented in six patients (86%). In the control group, atrial fibrillation occurred
in 35% and was the only presenting arrhythmia in 21%. Paroxysmal AV reentrant tachycardia was not documented in any patient in the study group and was documented in 67% of the control group ($p < 0.01$).

The study group and control group were similar in the incidence of associated cardiovascular disease and in sex distribution (table 1).

**Electrophysiologic Evaluation**

Patients in the study group were compared with the control group with respect to the following characteristics: (1) antegrade effective refractory period of the accessory pathway (fig. 1); (2) shortest paced atrial cycle length with 1:1 antegrade conduction over the accessory pathway (fig. 2); (3) mean RR interval during atrial fibrillation (fig. 3); (4) shortest RR interval between two consecutive preexcited beats during atrial fibrillation (fig. 4); and (5) location of the accessory pathway (table 1). None of these five characteristics distinguished patients with accessory pathways that conducted only in the antegrade direction from patients with accessory pathways that demonstrated bidirectional conduction.

Three of the seven patients in the study group had persistent ventriculoatrial dissociation during right ventricular pacing. Of the remaining four, two developed second-degree ventriculoatrial block at cycle length 500 msec or greater and one at cycle length 67% of the control group ($p < 0.01$).

### Table 1. Clinical Characteristics of the Patient Groups

<table>
<thead>
<tr>
<th></th>
<th>Exclusive antegrade conduction</th>
<th>Bidirectional conduction</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>7</td>
<td>111</td>
<td></td>
</tr>
<tr>
<td>Age at study (years)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>42</td>
<td>31.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Range</td>
<td>28–57</td>
<td>7–62</td>
<td></td>
</tr>
<tr>
<td>Sex: Male</td>
<td>4</td>
<td>74</td>
<td>NS</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>37</td>
<td>NS</td>
</tr>
<tr>
<td>Associated cardiovascular disease</td>
<td>1(14.3%)</td>
<td>16(14.4%)</td>
<td>NS</td>
</tr>
<tr>
<td>Spontaneous arrhythmias observed before study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>6(86%)</td>
<td>39(35%)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Paroxysmal atrioventricular reentrant tachycardia</td>
<td>0</td>
<td>67(60%)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Ventricular fibrillation</td>
<td>0</td>
<td>13(12%)</td>
<td>NS</td>
</tr>
<tr>
<td>None</td>
<td>1(14.3%)</td>
<td>11(16%)</td>
<td>NS</td>
</tr>
<tr>
<td>Accessory pathway location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left ventricular free wall</td>
<td>3(43%)</td>
<td>58(52%)</td>
<td>NS</td>
</tr>
<tr>
<td>Right ventricular free wall</td>
<td>1(14.3%)</td>
<td>21(19%)</td>
<td>NS</td>
</tr>
<tr>
<td>Septal</td>
<td>3(43%)</td>
<td>32(29%)</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Figure 1.** The antegrade effective refractory period of the accessory pathway in patients with exclusive antegrade accessory pathway conduction and patients with bidirectional accessory pathway conduction. The effective refractory period shown is the shortest measured, regardless of pacing site or cycle length.

**Figure 2.** The shortest cycle length with 1:1 antegrade conduction over the accessory pathway in patients with exclusive antegrade accessory pathway conduction and patients with bidirectional accessory pathway conduction. The cycle length recorded is the shortest obtained during right atrial and coronary sinus pacing.
300 msec. The fourth patient maintained 1:1 ventriculoatrial conduction to a cycle length of 240 msec. These seven patients met our criteria for absence of retrograde conduction over an accessory pathway (table 2). In patient 6, a distinct His deflection was not seen during right ventricular pacing. In patient 7, right atrial mapping was not performed because consistent right ventricular capture could not be obtained at a slow enough cycle length to allow for persistent ventriculoatrial conduction.

**TABLE 2. Criteria for Absence of Retrograde Accessory Pathway Conduction**

<table>
<thead>
<tr>
<th>1. Absence of reentrant tachycardia before or during study</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>Yes Yes Yes Yes Yes Yes Yes</td>
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<td>2. Ventriculoatrial dissociation at all cycle lengths tested</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Yes Yes Yes No* No No No</td>
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<tr>
<td>3. Atrial activation preceded by His deflection during ventricular refractory period</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>Yes</td>
<td>Yes</td>
<td>No†</td>
<td>Yes</td>
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<td>NP NP NP Yes Yes Yes NP†</td>
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<tr>
<td>4. Coronary sinus and right atrial mapping demonstrated atrial activation began in septum and moved laterally during ventricular pacing</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NP†</td>
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<td>NP NP NP Yes Yes Yes NP†</td>
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<td>5. Atrial activation during premature ventricular stimuli similar to 4</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>6. Atrial activation during 2° VA block similar to 4</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>NP NP NP Yes Yes Yes Yes</td>
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*Ventricular pacing cycle length (msec) when VA block occurred.
†His deflection not observed.
‡Right atrial mapping not performed; however, atrial activation occurred first in the septum and then in the right atrium and coronary sinus.

**FIGURE 3. Mean RR interval during atrial fibrillation in patients with exclusive antegrade accessory pathway conduction and patients with bidirectional accessory pathway conduction.**

**FIGURE 4. The shortest RR interval between two preexcited beats during atrial fibrillation in patients with exclusive antegrade accessory pathway conduction and patients with bidirectional accessory pathway conduction.**

**Discussion**

**Prevalence of Accessory Pathways with Exclusive Antegrade Conduction**

The prevalence of patients with accessory pathways that conduct only in the antegrade direction is unknown. We observed seven such patients during a time period when we saw 111 patients with bidirectional accessory pathway conduction and 25 patients with exclusive retrograde accessory pathway conduction. However, our patients are a selected group who have failed medical management and are being considered...
for surgical correction of Wolff-Parkinson-White syndrome. Wellens and Durrer\textsuperscript{10} reported eight of 36 patients (22\%) who demonstrated no ventriculotra
torial conduction over their accessory pathway, while Zipes et al.\textsuperscript{9} reported one patient with exclusive antegrade conduction. None of these nine reported cases ever demonstrated reciprocating tachycardia. Hindman et al.\textsuperscript{12} evaluated 27 patients with the Wolff-Parkinson-White syndrome with 24-hour Holter monitoring. They noted 10 patients who had no retrograde atrial conduction of spontaneous premature ventricular complexes. Retrograde conduction was either absent or not observed because the atrial depolarization was isoelectric to the lead being monitored or obscured by the QRS complex. Four of the 10 patients were taking quinidine (for treatment of palpitations), which may have altered the conduction characteristics of their accessory pathway. The remaining six patients with delta waves on their ECG and no documented episodes of reciprocating tachycardia may have had no retrograde conduction. These six patients (22\%) may reflect the true prevalence of accessory pathways capable of only antegrade conduction in patients who are less symptomatic than the group reported in our study. These patients would only be considered for treatment should they develop symptomatic atrial fibrillation.

**Clinical Characteristics**

Patients with accessory pathways that conducted only in the antegrade direction presented at an older age and with a higher frequency of atrial fibrillation than the control group. The 35\% prevalence of atrial fibrillation in our control group is similar to the reported prevalence of this arrhythmia in other large populations of patients with the Wolff-Parkinson-White syndrome.\textsuperscript{13, 14} The higher incidence of atrial fibrillation in patients with accessory pathways demonstrating only antegrade conduction is expected because this is the most likely arrhythmia that would cause the patient to seek medical attention. Atrial fibrillation occurs more often in older persons,\textsuperscript{18} and our study group reflects this trend. Of the six patients with atrial fibrillation documented before the electrophysiologic study, one had rheumatic mitral valve disease with left atrial enlargement and another had severe asthma that required chronic \(\beta\)-sympathomimetic treatment. None of the remaining four patients had identifiable etiologies of atrial fibrillation.

None of the seven patients in the study group had a history of paroxysmal AV reentrant tachycardia or antidromic reciprocating tachycardia (using the accessory pathway for conduction in the antegrade direction and the AV node for conduction in the retrograde direction). The functional properties of the AV nodes in most of the patients made this arrhythmia unlikely.\textsuperscript{19}

**Differential Diagnosis**

Two explanations for the electrophysiologic findings in these patients are (1) that they had nodoven-

tricular (Mahaim) connections that conducted only in the antegrade direction\textsuperscript{13} and (2) that their accessory pathway was traumatized during the electrophysiologic study.\textsuperscript{10} The first explanation is unlikely for several reasons. Mahaim fibers with bidirectional conduction are less common than AV fibers. Additionally, in one of our patients conduction over the AV node was not altered after the accessory pathway was surgically incised, which proves that the accessory pathway connected the atrium and ventricle and was not a Mahaim connection. The second explanation is also unlikely. Catheter trauma resulting in a poorly functioning or nonfunctioning accessory pathway has been reported, but catheter trauma that results in the inability of a pathway to conduct retrogradely while maintaining normal antegrade functional properties has not been reported. We studied our last three patients while directing attention toward eliminating catheter trauma. One patient with a left-sided accessory pathway demonstrated complete ventricular dissociation at all right ventricular pacing cycle lengths tested before a coronary sinus catheter was introduced. Thus, in this patient, catheter trauma was not a possible etiology for the failure of the accessory pathway to conduct in the retrograde direction.

The functional properties in the antegrade direction of the accessory pathways in the study group were similar to the control group despite the absence of retrograde conduction. DeLa Fuente et al.\textsuperscript{20} studied a tissue model of the Wolff-Parkinson-White syndrome that demonstrated unidirectional conduction block may be present when a narrow strand of tissue abruptly inserts into a larger mass of tissue. However, the functional properties of the tissue were not evaluated. Therefore, unidirectional accessory pathways can be demonstrated in the laboratory, but why the functional properties are not changed is unclear.

**Clinical Implications**

Asymptomatic patients with delta waves on their ECGs may have accessory pathways that conduct only in the antegrade direction. As these patients age, they may present with atrial fibrillation. If atrial fibrillation does occur, it should be treated similarly to that of other patients with the Wolff-Parkinson-White syndrome.

**Acknowledgment**

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**References**

2. Coumel P, Attuel P: Reciprocating tachycardia in overt and lat-