Electrophysiologic and Pharmacologic Characteristics of Automatic Ectopic Atrial Tachycardia

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SUMMARY In seven children six weeks to nine years of age, the diagnosis of chronic atrial tachycardia due to an automatic ectopic focus was established by clinical course, by the recording of intracardiac electrograms, and by atrial stimulation during cardiac catheterization. Both overdrive atrial pacing and programmed premature atrial stimulation failed to influence the tachycardia. Digoxin-re-established sinus rhythm in one patient while it slowed the tachycardia rate slightly in six. Propranolol with digoxin was effective in restoring sinus rhythm in three cases, ineffective in one, and slowed the rate in two. Diphenhydantoin was effective in one of two patients in whom it was used. Reserpine restored sinus rhythm in the one patient to whom it was given. Although automatic ectopic atrial tachycardias are difficult to manage, an aggressive diagnostic and pharmacologic program results in a high degree of control.

NEW ELECTROPHYSIOLOGICAL TECHNIQUES have allowed the classification of atrial tachycardia into two major types: automatic ectopic focus and re-entry.2 11 The ectopic focus type is rare in adults but often occurs in children.3 4 11 It is likely that treatment of these two types of tachycardia will be different.15 16 It is the purpose of this report to observe the response of ectopic atrial tachycardia to atrial pacing and to long term drug treatment.

Methods

Seven patients, six weeks to nine years of age were studied. Each subject was first evaluated by history and physical examination, 15 lead electrocardiography and chest roentgenography. All medications were discontinued 24 hours before the study. All except the youngest were sedated with meperidine 2 mg/kg, chlorpromazine 0.5 mg/kg, and promethazine 0.5 mg/kg, 30 minutes before the study. Two electrode catheters were inserted percutaneously into the femoral veins and positioned in the right heart under fluoroscopic and electrocardiographic control for His bundle potential and atrial recording as previously reported.14 In one case, an additional quadripolar electrode catheter was positioned in the coronary sinus after percutaneous insertion in a left anteceubital vein. Right atrial pacing at a rate slightly faster than the existing tachycardia was carried out in six patients with a Med Data MD-1 rapid stimulator, and recordings were made during abrupt termination of pacing. In five subjects, single, progressively more premature atrial beats were then introduced during existing tachycardia by coupling to the atrial electrogram with a Medtronic 5837 stimulator. External cardioversion with 2 watt seconds/kg of body weight was done in six patients.

In three subjects who had periods of sinus rhythm during the study, premature atrial beats were coupled into their sinus rhythm. In four subjects, propranolol 0.1 mg/kg i.v., over ten minutes was given during the study and in three, xylcaine, 1 mg/kg i.v. bolus was also administered.

In each case, digoxin was selected as the initial drug for chronic treatment of their tachycardia. If digoxin proved ineffective, a second drug was added. Before declaring any drug ineffective, the dose was increased until clinical signs of mild toxicity developed or the serum level was in the upper

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part of the effective range. The results of treatment were observed clinically by electrocardiogram and by 12 and 24 hour ambulatory tape recordings of ECG at follow-up periods ranging from six months to seven years.

Results

Surface electrocardiography showed repetitive tachycardia in four patients and persistent tachycardia in three, according to the definition of Keane et al.13 (figs. 1 and 2). Distinct P waves could be seen in the tracing of each of the seven. The rate of the tachycardia varied from day to day and minute to minute.

The mechanism of tachycardia was determined in each case to be an automatic ectopic focus, based on the criteria of Goldreyer et al.3 and Scheinman et al.4 The tachycardia could not be started or stopped by either overdrive atrial pacing or single premature atrial beats. The initial complex of the tachycardia had the same P wave morphology and atrial activation sequence as the ensuing complexes. In all cases, the ectopic focus was in the atrium. By recording from the high and low right atrium the ectopic focus was low atrial in two patients, near the sinus node in two, and approximately equidistant in the others (table 1). In patient 7, in whom left atrial depolarization was recorded from an electrode in the coronary sinus, the left atrium showed the earliest depolarization (fig. 3). There was an associated cardiomyopathy present in patients 4, 6 and 7. As these patients all had tachycardia, it was impossible to establish whether the cardiomyopathy was primary or secondary to tachycardia.

Overdrive atrial pacing temporarily depressed the rate of the ectopic focus in all six cases in which this was performed.

FIGURE 1. The onset of an automatic ectopic supraventricular tachycardia recorded on lead II of the surface electrocardiogram of patient 1. There is a gradual increase in rate, together with a gradual increase in PR interval. P waves are clearly visible except at the fastest rate.

FIGURE 2. Fifteen lead electrocardiogram of patient 7 during left atrial automatic ectopic tachycardia. The P waves are negative in leads I and aV1, positive in II, III, and aVF, and show a dome and dart pattern in the right precordial leads.
The degree of depression was variable as was the escape mechanism after pacing. The mechanism was sinus for one to four beats in three cases and ectopic in four. In no instance did overdrive pacing suppress the ectopic mechanism for over two seconds.

Introduction of single premature beats during tachycardia resulted in a pause which became progressively less than compensatory as the premature atrial contraction was introduced earlier into the atrial cycle (fig. 4). The shape of the curve showing this relationship is similar to that recorded by introducing premature beats during sinus rhythm in normal subjects (fig. 5). This curve is qualitatively different from that obtained from patients with re-entry mechanism atrial tachycardia (fig. 6).

Cardioversion was unsuccessful in all patients.

In all patients, digoxin was the first drug given. In patient 3, digoxin completely suppressed the tachycardia for one year and there was no recurrence after stopping treatment during a two-year follow-up. In the other five patients, although digoxin aided in the control of congestive heart failure, it did not depress the tachycardia rate significantly.

Propranolol, 1-3 mg/kg/day in four divided doses, together with digoxin was the next regimen tried in six cases. In one patient, propranolol had no detectable effect on rate or rhythm. In three patients, propranolol suppressed the ectopic focus completely and allowed sinus rhythm to resume. One of these three had no recurrence on discontinuing the drug after one year, while the other two continued to require the drug. Propranolol decreased the rate of the other two patients' tachycardias from 180-240 beats/min to 90-125 beats/min, but the focus remained unchanged (GC in table 1). Diphenylhydantoin (DPH) was used in the other two patients. In each, oral digoxin was continued while the DPH was administered, initially intravenously, at a dose of 4 mg/kg every six hours until the serum level was greater than 20 mg/ml (therapeutic range for seizures, 10-18 mg/ml). In case 2, on a day when the DPH level was 30 mg/ml, the patient was in sinus rhythm for 20 hours out of 24. For the remainder of the time, she was in ectopic tachycardia but at a rate of only 120. Careful neurologic examination failed to reveal any sign of DPH toxicity. In the other patient, DPH failed to influence the tachycardia.

Reserpine was used in this patient when digoxin, propranolol, DPH and quinidine had failed. It was administered initially intramuscularly, followed by 0.18 mg/day orally (body weight 7 kg). This resulted within 18 hours in sinus rhythm, which was maintained for nine months. At that time, it was felt that she was depressed psychologically, and the dose was decreased. The tachycardia then resumed. When the dose was again increased, sinus rhythm resumed. The depression was not considered to be as significant as the tachycardia. Digoxin and DPH were continued with reserpine.

Discussion

The diagnosis of automatic ectopic focus atrial tachycardia may be suspected from the surface ECG. In all of our patients, P waves were clearly visible. This is the exception in cases of re-entry atrial tachycardia. The onset of tachy-

**Table 1.**

<table>
<thead>
<tr>
<th>Case/Age/Sex</th>
<th>Site</th>
<th>Digoxin</th>
<th>Digoxin + propranolol</th>
<th>DPH</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/9 y/F</td>
<td>HA</td>
<td>±</td>
<td>+</td>
<td>NA</td>
<td>NSR</td>
</tr>
<tr>
<td>2/8 m/F</td>
<td>LoA</td>
<td>±</td>
<td>+</td>
<td>GC</td>
<td></td>
</tr>
<tr>
<td>3/4 m/F</td>
<td>MA</td>
<td>±</td>
<td>+</td>
<td>NA</td>
<td>NSR</td>
</tr>
<tr>
<td>4/2 y/M</td>
<td>LoA</td>
<td>±</td>
<td>NA</td>
<td>NA</td>
<td>GC</td>
</tr>
<tr>
<td>5/6 wk/F</td>
<td>LoA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>N5R</td>
</tr>
<tr>
<td>6/3 m/F</td>
<td>HA</td>
<td>±</td>
<td>+</td>
<td>NA</td>
<td>NSR</td>
</tr>
<tr>
<td>7/5 y/M</td>
<td>LA</td>
<td>-</td>
<td>+</td>
<td>NA</td>
<td>NSR</td>
</tr>
</tbody>
</table>

**Abbreviations:** HA = high right atrium; LoA = low right atrium; MA = midatrium; LA = left atrium; NA = not attempted; GC = good control; NSR = normal sinus rhythm; ± = effective; - = not effective; ± = partially effective in relief of symptoms; DPH = diphenylhydantoin.
ectopic tachycardia was gradual in many cases (fig. 1). In cases of repetitive tachycardia the shape of the P wave of the first beat was the same as that of the subsequent beats. The PR interval during tachycardia was often but not always normal, whereas a prolonged PR interval is a hallmark of re-entry tachycardias. The diagnosis of an ectopic focus is confirmed by intracardiac stimulation studies.5-6, 11

In case 7, the intracardiac studies also confirmed that the ectopic focus was in the left atrium. This had already been suggested by the negative P waves in leads I and aV_{L} on the surface ECG (fig. 2). This is the first confirmation of the ECG diagnosis of a left atrial spontaneous ectopic focus in man. This confirms that the diagnosis of left atrial rhythm can be made based on the criteria of negative P waves in leads I and aV_{L}, positive P waves in II, III and aV_{F}.16-18 This patient also demonstrated notched P waves in lead V_{1}, suggestive of the dome and dart pattern.16

Recent studies by Wit and Cranefield15 have shown that it is possible to trigger repetitive extrasystoles and sustained tachycardias in cardiac fibers with slow action potentials.10 These rhythms were not thought to be due to re-entry, thus casting some doubt on currently used clinical techniques or differentiating re-entry from ectopic foci. These fibers were under abnormal conditions of external potassium and catecholamine stimulation and the situation may not be clinically applicable in the absence of myocardial infarction. In any event, the clinical electrophysiologic division into ectopic versus re-entry mechanisms is useful in that it

![Figure 4](http://circ.ahajournals.org/)

Figure 4. Response of an ectopic atrial tachycardia to a single premature atrial beat in patient 1. The tachycardia cycle length of 385 msec is interrupted by a premature stimulus at 290 msec which is not conducted to the bundle of His. The tachycardia then resumes after a less than compensatory pause. Recorded are surface leads I, aV_{F}, V_{1}, together with a high right atrial electrogram (HRA) and a His bundle electrogram.

![Figure 5](http://circ.ahajournals.org/)

Figure 5. Graph of the typical response of an atrial ectopic tachycardia to single programmed atrial extra stimulus in patient 5. A_{1},A_{2} represents the interval from a spontaneous atrial ectopic beat during tachycardia to the premature beat. A_{1},A_{2} represents the interval from the premature beat to the next beat which was always from the ectopic focus in this case. The dots represent the control state and the x's represent a repeat study after intravenous propranolol. Propranolol markedly depressed the automaticity of the ectopic focus.

![Figure 6](http://circ.ahajournals.org/)

Figure 6. Graph of the response of a re-entry supraventricular tachycardia to progressively more premature stimuli. As the prematurity increased, the return cycle lengthened gradually until the re-entry cycle was broken and a sinus beat intervened as evidenced by a marked sudden increase in return cycle length.
separates patients into two groups which respond differently to management.

Infants and children with automatic ectopic atrial tachycardia are usually very difficult management problems. Based on our studies and those of others, it is evident that one reason for this is the ineffectiveness of digoxin. Electrical cardioversion and overdrive pacing are also ineffective because they only suppress the focus for, at most, a few seconds. Electroversion was unsuccessful in each of six patients in whom it was attempted in this series. Each of the seven patients had either overdrive pacing or electroversion.

The majority of our cases seem to be similar to those which are classified as chronic atrial tachycardia by Keane and Nadas and by Jacobsen et al. They also noted the difficulty in treatment and the serious side effects such as strokes and congestive heart failure in some patients. Others persist in tachycardia for years without symptoms.

The properties of these ectopic pacemakers are similar to those of the sinus node in that they are responsive to changes in autonomic tone and the rate varies from time to time. The response to premature atrial stimulation is also similar to the sinus node in that the ectopic pacemaker is reset by the premature beat to a degree proportional to the prematurity.

Although the use of antidyssrhythmic agents is still empirical, we believe that if an ectopic focus is suspected, certain drugs are more likely to be effective. Digoxin is the most frequently successful agent in breaking re-entry circuits, but as shown in this study it is rarely successful in ectopic foci. It should still be used routinely since it aids in the prevention of congestive heart failure and may slow the ventricular rate due to A-V block. Propranolol is frequently effective in both forms of tachycardia. Signs of congestive heart failure must be watched for, particularly if there is an associated cardiomyopathy.

Xylocaine may be a useful drug for acutely slowing the rate of the supraventricular ectopic focus. In cases in which second degree A-V block is present, however, the ventricular rate may be increased when one to one conduction occurs in one of our cases. It is possible that a xylocaine-like drug for oral usage will be developed and may be effective in this condition.

Diphenylhydantoin may be effective both acutely and for chronic administration. It appears that the therapeutic and toxic blood levels are very close to each other, and this limits its effectiveness for long term management.

Reserpine is the final drug with which we have had a favorable response. Further studies on more patients will be necessary before its effectiveness can be evaluated.

Surgical treatment should be possible in extremely severe cases and could consist of the direct removal of the ectopic focus or division of the bundle of His with insertion of a pacemaker.

In this study we have achieved complete control of the tachycardia with resumption of sinus rhythm in five of seven cases. In the other two, the rate was slowed to a level associated with relief of symptoms. Atrial ectopic tachycardias are not uncommon in children. Although their management is difficult, it may be successful if drug combinations are used rationally.

References

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