Effects of Procainamide on Atrioventricular Nodal Re-entrant Paroxysmal Tachycardia

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SUMMARY Electrophysiological effects of 750 mg i.v. procainamide were studied in 14 patients with dual pathway atrioventricular (A-V) nodal re-entrant paroxysmal tachycardia (PSVT). All patients utilized an A-V nodal slow pathway for antegrade and an A-V nodal fast pathway for retrograde conduction during PSVT. In all 14 patients, procainamide depressed retrograde fast pathway conduction, manifest by increase in mean ± SEM ventricular paced cycle length (CL) producing V-A block from ≥295 ± 25 to 385 ± 17 msec (P < 0.001). Antegrade fast and slow pathway properties were unchanged with procainamide.

Eleven of the 14 patients had induction of sustained PSVT before procainamide. Eight of these lost ability to induce or sustain PSVT after procainamide, reflecting depression of retrograde fast pathway conduction with either absence of atrial echoes (4 pts) or induction of nonsustained PSVT, with termination of PSVT occurring after QRS (retrograde block in fast pathway) (4 pts). In three of these 11 patients, sustained PSVT was inducible before and after procainamide (mean CL of 395 ± 38 and 395 ± 40 respectively) (NS).

Three patients had induction of nonsustained PSVT before procainamide. In two, induction of sustained PSVT occurred after procainamide due to enhanced antegrade slow pathway conduction, while in the other PSVT remained nonsustained.

In conclusion, procainamide inhibited induction of sustained A-V nodal re-entrant PSVT in most patients, reflecting selective depression of retrograde A-V nodal fast pathway conduction. In a minority of patients, vagolytic effects of procainamide potentiated induction of sustained PSVT.

ELECTROPHYSIOLOGICAL STUDIES have demonstrated atrioventricular (A-V) nodal re-entry to be the most common mechanism of paroxysmal supraventricular tachycardia (PSVT). The ability to induce and terminate A-V nodal re-entrant PSVT in the catheterization laboratory has allowed evaluation of drug effects on induction of this arrhythmia. Previous studies have been concerned with the effects of intravenous ouabain, propranolol, and verapamil on the induction of A-V nodal re-entrant PSVT.

Both quinidine and procainamide have been recommended for treatment of the acute attack and for prevention of PSVT. Despite these recommendations, little is known about the effects of these agents upon the induction and maintenance of A-V nodal re-entrant PSVT. In this study, we thus examine the acute electrophysiological effects of procainamide on induction and maintenance of A-V nodal re-entrant PSVT. In addition, observations are made concerning the effects of procainamide on antegrade and retrograde A-V nodal fast and slow pathway properties.

Methods

Patient Selection

Criteria for inclusion in this study included 1) a history of electrocardiographically documented recurrent paroxysmal supraventricular tachycardia; 2) absence of pre-excitation on all available electrocardiograms; 3) electrophysiological diagnosis of A-V nodal re-entrant PSVT utilizing atrial stimulatory techniques, ventricular stimulatory techniques, and mapping of atrial activation sequence during induced tachycardia. In all patients, PSVT was characterized by antegrade slow pathway and retrograde fast pathway conduction (see below). Patients with the unusual variety of A-V nodal re-entry (antegrade fast and retrograde slow pathway) were not observed in this study.

Fourteen patients, eight males and six females, with ages between 20 and 80 (mean ± SD of 57 ± 17) years, were studied.

Electrophysiological Studies

Electrophysiological studies were performed in the postabsorptive, non sedated state after obtaining written, informed consent. All cardiac drugs were discontinued at least three days prior to study. A tripolar electrode catheter was positioned across the tricuspid valve percutaneously via a femoral vein for His bundle recording. A second hexapolar catheter was positioned at the right ventricular apex via an antecubital vein. The distal two electrodes (tip) were utilized for ventricular pacing, the middle two electrodes (10 cm from the tip) for recording of high right atrial electrograms, and proximal two electrodes (13.5 cm from the tip) for atrial pacing. A third bipolar electrode catheter was positioned in the distal coronary sinus via another antecubital vein for recording of left atrial electrograms. Multiple electrocardiographic leads and intracardiac electrograms were simultaneously recorded on a multichannel oscilloscopic photographic recorder (Electronics for Medicine, DR-16) at paper speeds of 200 and 100 mm/sec. Stimuli were provided by a programmable digital stimulator (manufactured by M. Bloom), with a strength of approximately twice diastolic threshold and two msec in duration.

Conduction properties were evaluated utilizing 1) incremental atrial pacing; 2) atrial extrastimulus testing at...
sinus and at a driven atrial cycle length; 2) incremental ventricular pacing; 4) ventricular extrastimulus testing at a ventricular driven cycle length slightly shorter than sinus rhythm; 5) mapping of retrograde atrial activation sequences from multiple atrial sites during induced PSVT; 6) atrial and ventricular extrastimulus testing during induced PSVT. After the control study, procainamide 750 mg (in 50 ml 5% dextrose water) was infused intravenously over a period of 20 minutes and the studies were repeated immediately. Atrial and ventricular extrastimulus testing was performed at cycle lengths identical to control. In each patient, the study was completed within 30 minutes after procainamide administration. In four patients, blood was taken for measurement of serum procainamide levels 20 minutes after infusion. These levels ranged from 4 to 8 μg/cc (mean ± sd of 5.7 ± 1.6), and were consistent with previous reported levels with the dosage regimen described above.\(^{23,24}\)

**Electrophysiological Definitions**

HRA\(_1\), A\(_1\), H\(_1\), and V\(_1\) were respectively the high right atrial, low septal right atrial, His bundle, and ventricular responses to driven stimuli (S\(_1\)). HRA\(_2\), A\(_2\), H\(_2\), and V\(_2\) were respectively the high right atrial, low septal right atrial, His bundle and ventricular response to the test stimuli (S\(_2\)). Conduction intervals, refractory periods, echo zones, and critical A-H and V-A intervals (for induction of A-V nodal reentrant echoes and PSVT) were measured and defined as previously described.\(^{17}\)

Antegrade dual A-V nodal pathways were diagnosed when discontinuous A\(_2\)-A\(_3\), H\(_2\)-H\(_3\) curves were demonstrated. Both antegrade and retrograde effective refractory periods of the fast and slow pathway were defined as previously described.\(^{3,4,13-20}\)

The diagnosis of A-V nodal re-entrant PSVT was made utilizing combinations of the following diagnostic criteria: 1) induction of PSVT related to achievement of a critical A-H delay, with both incremental atrial pacing and with atrial extrastimulus testing;\(^{9,13,15,20}\) 2) demonstration of discontinuous A\(_2\)-A\(_3\), H\(_2\)-H\(_3\) curves, suggesting dual A-V nodal pathway, with induction of PSVT relating to antegrade block in the fast pathway.\(^{3,4,13-20}\) Since both criteria could also be fulfilled in patients with concealed extranodal pathways, one or more of the following additional criteria were required for the diagnosis of A-V nodal re-entry.:\(^{20,31}\)

3) demonstration of atrial activation before or simultaneous with onset of ventricular activation during PSVT, suggesting that the ventricles were not part of an A-V re-entrant circus movement;\(^4\) 4) normal retrograde atrial activation sequence during PSVT, with slow septal right atrium being activated earlier than all other atrial recording sites;\(^{21,32}\) 5) increase of V-A interval with incremental ventricular pacing with type I V-A block at the critical rate, suggesting retrograde A-V nodal conduction; 6) demonstration of His bundle activation (H\(_3\)) preceding the atrial activation (A\(_3\)) with ventricular extrastimulus testing during ventricular pacing and/or PSVT, suggesting retrograde A-V nodal conduction;\(^4\) 7) absence of previously described criteria for diagnosis of concealed extranodal pathways.\(^{20,31}\)

Sustained PSVT was defined when induced PSVT lasted longer than two minutes, requiring electrical termination with single or double extrastimuli. Nonsustained PSVT was defined when induced PSVT terminated spontaneously.

**Table 1. Effects of Procainamide on Induction of A-V Nodal Re-entrant Tachycardia**

<table>
<thead>
<tr>
<th>Case</th>
<th>PSVT</th>
<th>Antegrade (msec)</th>
<th>Retrograde (msec)</th>
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<tr>
<td></td>
<td></td>
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<tr>
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<td>Yes</td>
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<tr>
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<td>Yes</td>
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<td></td>
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**Abbreviations:** PSVT = paroxysmal supraventricular tachycardia; CL = cycle length; BCL = basic driving cycle length; PP-ERP = effective refractory period of the fast pathway; SP-ERP = effective refractory period of the slow pathway; CL-AVB = longest cycle length producing A-V block; VACS-ERP = effective refractory period of the ventriculioatrial conducting system; CL-VAB = longest cycle length producing V-A block; C = control; PA = procainamide.
Results

PSVT Induction (table 1)

Sustained A-V nodal re-entrant PSVT was inducible in 11 of the 14 patients before procainamide (cases 1-11) (figs. 1-3). In nine, PSVT was inducible with incremental atrial pacing (cases 1-5, 7 and 9-11) (figs. 1A and 2A); in ten with atrial extrastimulus testing (cases 1-7 and 9-11) (fig. 3A); and in three with incremental ventricular pacing (cases 3, 6 and 8) (fig. 1C). Induction of PSVT in the ten patients with atrial stimulation reflected antegrade failure of a fast A-V nodal pathway with resultant antegrade slow pathway conduction (figs. 1A, 2A, and 3A). Induction of PSVT in the three patients with ventricular stimulation reflected retrograde failure of a slow A-V nodal pathway as manifest by lack of critical V-A delay (fig. 1C).

Following procainamide administration, sustained PSVT could be induced in only three of these 11 patients (cases 9-11). In four of these patients (cases 5-8) PSVT was no longer sustained after procainamide (fig. 1B). In all of these four patients, PSVT ended when QRS complexes were not followed by atrial complexes (fig. 1B), suggesting failure in the retrograde limb of the circus movement (fast pathway). In the remaining four patients with sustained PSVT before

A

Control

Paced HR = 160

HRA

S S S S S S

HBE

A A A A A A A A

360

B

Procaine Amide

Paced HR = 150

HRA

S S S S S S

HBE

A A A A A A A A

450

C

Control

Paced HR = 200

HRA

S S S S S S

HBE

D

Procaine Amide

Paced HR = 120

HRA

S S S S S S

HBE

Figure 1. Recordings from case 6 showing failure to sustain paroxysmal supraventricular tachycardia (PSVT) after procainamide and effects of procainamide on retrograde conduction. Shown are electrocardiographic lead V1, high right atrial electrogram (HRA), and His bundle electrogram (HBE). A and H are atrial and His bundle electrogram, respectively. S represents stimulus artifact and E represents A-V nodal re-entrant atrial echo. Timelines are at one second and paper speed is 100 mm/sec in this and subsequent illustrations. Panel A demonstrates induction of sustained PSVT with rapid atrial pacing at a paced heart rate (HR) of 160 beats/min before procainamide. Panel B demonstrates induction of nonsustained PSVT after procainamide at an atrial paced rate of 150 beats/min. Note that termination of PSVT occurs when QRS complex is not followed by an atrial response, suggesting block in the retrograde fast pathway. Panel C demonstrates induction of sustained PSVT upon cessation of rapid ventricular pacing before procainamide. The ventricular paced rate is 200 beats/min (cycle length of 300 msec). Note intact 1:1 V-A conduction via fast pathway. Panel D demonstrates development of second degree V-A block at a slower ventricular paced rate of 120/min (cycle length of 500 msec) after procainamide. PSVT was not induced.
procainamide (case 1-4), neither PSVT or even single A-V nodal re-entrant atrial echoes, were demonstrated with atrial stimulation after procainamide administration (figs. 2B and 3B). The loss of atrial echoes occurred despite achievement of a critical slow pathway A-H after procainamide administration.

In three of the patients (cases 12, 13, and 14) only non-sustained PSVT could be induced prior to procainamide ad-

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**FIGURE 2.** Recordings from case 3 showing failure to induce PSVT after procainamide and effects of procainamide on retrograde conduction. Panel A demonstrates induction of sustained PSVT before procainamide upon cessation of rapid atrial pacing at a paced heart rate of 200 beats/min, which achieved an A-H interval of 230 msec. The third PSVT QRS complex from the right is a fusion with PVC. Panel B demonstrates failure to induce echoes or PSVT after procainamide at an atrial paced rate of 180 beats/min, despite achieving a longer A-H interval of 370 msec. Panel C demonstrates intact V-A conduction at a ventricular paced rate of 220 beats/min (cycle length of 261 msec) before procainamide. Panel D demonstrates development of second degree V-A block at a slower ventricular paced rate of 170 beats/min (cycle length of 353 msec) after procainamide.

**FIGURE 3.** Recordings from case 4 showing failure to induce echoes or PSVT after procainamide with atrial extrastimulus testing. A1 and H1 are atrial and His bundle responses to the driven stimuli (St); A2 and H2 are atrial and His bundle responses to the extrastimulus (St); A3 and H3 are atrial and His bundle responses to the second extrastimulus (St). The driven cycle length (CL), A1 - A2 and A2 - A3 intervals are listed on top of each panel while A2 - H2 or A3 - H3 intervals are listed on bottom of each panel. Panel A demonstrates induction of sustained PSVT before procainamide with single atrial extrastimulus at A1 - A2 of 230 msec, which achieved A2 - H2 interval of 350 msec (slow pathway). Panel B demonstrates failure to induce echoes or PSVT after procainamide with double atrial extrastimuli despite achieving a slow pathway A-H (A2 - H3) of 440 msec.
ministration (fig. 4A). In all three patients, spontaneous termination of PSVT occurred with atrial complexes not followed by H and QRS complexes, suggesting block in the antegrade limb of the circus movement (slow pathway) (fig. 4A). In these three patients, following procainamide administration, induced PSVT became sustained in two of the three patients (cases 13 and 14) (fig. 4B). In one of the patients, PSVT remained nonsustained. However, in the latter patient (case 12) spontaneous termination after procainamide occurred with QRS complexes not followed by atrial responses, suggesting block in the retrograde limb of the circus movement (fast pathway).

**PSVT Cycle Lengths (Table 1)**

The cycle lengths of PSVT before and after procainamide could be compared in those patients who either had nonsustained or sustained PSVT, both before and after drug administration (6 patients). PSVT cycle lengths ranged from 280 to 500 msec before procainamide administration (mean ± SEM PSVT cycle length of 407 ± 36 msec), and from 285 to 535 msec after procainamide (mean PSVT cycle length of 413 ± 39 msec) (NS).

**Conduction Curves and Echo Zone (table 1)**

Discontinuous $A_1$-$A_2$, $H_1$-$H_2$ curves suggesting dual A-V nodal pathways were demonstrated with atrial extrastimulus testing in 12 of the 14 patients (cases 1–7 and 9–13) before procainamide (figs. 5 and 6). All 12 patients had an echo zone (A-V nodal re-entrant atrial echoes) coinciding with the slow pathway curve. After procainamide, discontinuous $A_1$-$A_2$, $H_1$-$H_2$ curves persisted in eight patients (cases 3, 6, 7, and 9–13); in one (case 3) the echo zone was abolished (fig. 5). In four patients (cases 1, 2, 4, and 5), $A_1$-$A_2$, $H_1$-$H_2$ curves became continuous after procainamide; two (cases 4 and 5) due to an increase in atrial functional refractory period (longer than fast pathway effective refractory period) and in two (cases 1 and 2), due to a shortening of fast pathway effective refractory period (less than atrial functional refractory period) (fig. 6). Antegrade failure of the fast pathway was achieved in these four patients with double

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**Figure 4.** Recordings from case 13 showing potentiation of sustained PSVT after procainamide. CSA is atrial electrogram recorded for the coronary sinus. Panel A demonstrates induction of nonsustained PSVT with atrial extrastimulus testing before procainamide. Note that spontaneous termination of PSVT occurs when an atrial response is not followed by His bundle and ventricular response, suggesting block in the antegrade pathway (slow pathway). Panel B demonstrates induction of sustained PSVT with atrial extrastimulus after procainamide.
still continuous and the echo zone persisted. In the second patient with continuous curve without an echo zone (case 8), conduction was via the fast pathway (A-V nodal re-entrance having been demonstrated with incremental ventricular pacing). This patient still had a continuous curve after procainamide, again without an echo zone.

Retrograde Fast Pathway Properties (Table 1)

The loss of echo zone and the loss of ability to sustain PSVT after procainamide was explained by evaluation of retrograde fast pathway properties before and after drug administration. Retrograde fast pathway refractoriness was estimated by noting the ventricular paced cycle length producing retrograde V-A block.39 Before procainamide (14 patients), V-A block was noted at ventricular paced cycle lengths ranging from 261 to 375 msec (mean ± SEM of 305 ± 25 msec) (Figs. 1C and 2C). Following procainamide, the ventricular paced cycle length producing V-A block ranged from 300 to 500 msec (mean 385 ± 17 msec) (Figs. 1D and 2D) (P < 0.001).

In all 11 patients (cases 1–11) with induction of sustained PSVT before procainamide, the cycle length of PSVT (mean ± SEM of 365 ± 15 msec) was longer than the ventricular paced cycle length producing V-A block (mean 312 ± 11 msec). In the eight patients in whom induction of sustained PSVT was no longer possible after procainamide (cases 1–8), the drug produced enough depression of retrograde fast pathway refractoriness, so that the cycle length producing V-A block (mean 405 ± 22 msec) was longer than the cycle length of PSVT observed before procainamide (mean 354 ± 14 msec). In the three patients in whom induction of sustained PSVT was demonstrable after procainamide (cases 9–11), the cycle length producing V-A block (mean 343 ± 30 msec) was shorter than the cycle length of PSVT both before procainamide (mean 395 ± 38 msec) and after procainamide (mean 395 ± 40 msec). In the two patients with induction of nonsustained PSVT before procainamide (cases 13 and 14), and sustained PSVT after procainamide, the ventricular paced cycle length producing V-A block (mean 308 ± 8 msec before procainamide, and 325 ± 5 msec after procainamide) was shorter than the cycle length of PSVT (mean 465 ± 10 msec). In both of these

![Figure 5](https://circ.ahajournals.org/doi/fig/10.1161/01.CIR.57.6.1176)

**Figure 5.** Antegrade conduction curves in case 3 before and after procainamide showing dual A-V nodal pathways and abolition of echo zone after procainamide. The left panel shows discontinuous A1-A2, A2-H2 and A3-A2, H2-H3 curves suggesting dual A-V nodal pathways before procainamide. The fast pathway effective refractory period was 315 msec, and the slow pathway was less than 290 msec. The echo zone (open circles) was defined at A1-A2 between 315 and 290 msec, and coincided with the whole slow pathway curve. The critical A-H interval was 190 msec. The right panel shows discontinuous A1-A2, A2-H2 and A3-A2, H2-H3 curves after procainamide. The effective refractory periods of the fast and slow pathways were unchanged, but the echo zone was abolished despite maintenance of discontinuous curves with achievement of longer A2-H2 intervals after procainamide.

![Figure 6](https://circ.ahajournals.org/doi/fig/10.1161/01.CIR.57.6.1176)

**Figure 6.** Antegrade conduction curves in case 1 before and after procainamide showing dual A-V nodal pathways and abolition of echo zone after procainamide. The left panel shows discontinuous A1-A2, A2-H2 and A3-A2, H2-H3 curves before procainamide. The effective refractory periods of the fast and slow pathways were respectively 400 and 300 msec. The echo zone was coincided with the slow whole pathway curve. The critical A-H interval was 270 msec. The middle panel shows continuous A1-A2, A2-H2 and A3-A2, H2-H3 curves with abolition of echo zone after procainamide due to decrease of fast pathway effective refractory period. A-V conduction was limited by atrial functional refractory period of 320 msec. The right panel shows discontinuous A2-A3, A3-H3 curve after procainamide. Note that despite demonstration of discontinuous curve with achievement of longer A-H intervals, A-V nodal re-entrant echoes did not occur.
patients, retrograde fast pathway refractoriness was not the limiting factor producing nonsustained PSVT before procainamide.

The retrograde effective refractory period of the ventriculo-atrial conduction system could be compared utilizing ventricular extrastimulus testing in nine of the patients before and after procainamide (cases 1, 3–6, 8, 9, 12 and 14). The mean retrograde effective refractory period increased from \( \pm 265 \pm 11 \) to \( 335 \pm 23 \) msec after procainamide \( (P < 0.05) \). In three of the nine patients, retrograde His bundle potential were visualized before and after procainamide and the site of block could be localized to the A-V node. In the remaining patients, because retrograde His bundle potentials could not be recorded, the site of failure during retrograde conduction with ventricular extrastimulus testing could not be determined.

Antegrade Slow Pathway Properties (table 1)

Conduction in the antegrade limb of the circus movement (slow pathway) was evaluated by noting the atrial paced cycle length producing A-V nodal Wenckebach periods before and after procainamide administration.\(^3\) The atrial paced cycle length producing A-V nodal Wenckebach periodicity ranged from 261 to 430 msec before procainamide (mean \( \pm \) SEM \( \pm 331 \pm 16 \)), and from 260 to 430 msec after procainamide (mean \( \pm 346 \pm 14 \)) \( (NS) \). Although there was no statistically significant change in antegrade slow pathway refractoriness after procainamide, a slight decrease in antegrade slow pathway refractoriness in two patients with nonsustained PSVT prior to procainamide (cases 13 and 14) was enough to allow PSVT to be sustained after the drug (figs. 4A and 4B).

Antegrade slow pathway effective refractory periods, measured with atrial extrastimulus technique, could be compared in only two patients before and after procainamide (in the remaining patients, A-V conduction was atrial limited either before and/or after procainamide administration). In one of these patients (case 10), antegrade slow pathway effective refractory period decreased by 10 msec. In the other patient (case 13) antegrade slow pathway effective refractory period decreased by more than 80 msec.

In the 11 patients (cases 1–11) with induction of sustained PSVT before procainamide, the cycle length of PSVT (mean \( 365 \pm 15 \) msec) was longer than the atrial paced cycle length producing A-V block (mean \( 307 \pm 11 \) msec). In the eight patients who lost the ability to sustain PSVT after procainamide (cases 1–8) and the three patients who maintained the ability to sustain PSVT after procainamide (cases 9–11), the cycle length of PSVT was still longer than the atrial paced cycle length producing A-V block. This was consistent with the observation that the antegrade limb was not the limiting factor in the induction of sustained PSVT either before or after procainamide in these 11 patients.\(^2\)

Antegrade Fast Pathway Properties (table 1)

Antegrade fast pathway effective refractory periods could be compared before and after procainamide in the eight patients (cases 3, 6, 7 and 9–13) who had discontinuous conduction curves both before and after drug administration (fig. 5). Antegrade fast pathway effective refractory periods ranged from 260 to 410 msec before procainamide (mean of \( 333 \pm 19 \) msec), and from 250 to 440 msec after procainamide (mean \( 326 \pm 24 \) msec) \( (NS) \).

Discussion

The circus movement in patients with A-V nodal re-entrant PSVT usually consists of the following components: The slow A-V nodal pathway (antegrade limb), the distal common pathway (probably intra A-V nodal), the fast A-V nodal pathway (retrograde limb), and the proximal common pathway (probably intra A-V nodal).\(^9\)–\(^14\) Induction of PSVT in these patients depends on antegrade block of impulses in the fast pathway, with sufficient conduction delay in the slow pathway, allowing the previously blocked fast pathway to recover and allow retrograde conduction.

Atrial extrastimulus testing in these patients frequently demonstrates discontinuous A1-A2, and H1-H2 curves, reflecting failure of antegrade conduction in the fast pathway with resulting slow pathway conduction, at close A2-A3 coupling intervals.\(^3\)–\(^4\) In contrast, ventricular extrastimulus testing frequently demonstrates continuous V1-V2, A1-A2 curves with retrograde fast pathway conduction at all V1-V2 coupling intervals.\(^17\)–\(^19\) Induction of sustained A-V nodal re-entrant PSVT with dual A-V nodal pathway relates to measurable fast and slow pathway properties.\(^30\)–\(^32\) Specifically, sustained PSVT occurs in dual A-V nodal pathway patients who have capability for repetitive antegrade slow pathway conduction and repetitive retrograde fast pathway conduction.\(^33\) The ability for the former is estimated by noting the shortest atrial paced cycle length allowing the intact A-V conduction. The ability for the latter is estimated by noting the shortest ventricular paced cycle length allowing intact ventriculoatral conduction. Lack of ability to sustain PSVT usually reflects either depressed antegrade slow pathway conduction or depressed retrograde fast pathway conduction.

The cycle length of tachycardia in a patient with dual pathway A-V nodal re-entrant PSVT reflects the sum of the conduction times in all components of the re-entrant circuit. The ability to sustain PSVT depends upon the cycle length of PSVT being longer than the refractory period of any of the components of the re-entrant circuit. If block develops in a component of the re-entrant circuit during PSVT, the arrhythmia terminates.

Pharmacological agents which increase refractoriness of one or more component of the circuit (without offsetting this increase by lengthening conduction time elsewhere in the circuit as well) can prevent induction of sustained A-V nodal re-entrance. Previous studies demonstrate that propranolol, ouabain, and verapamil often increase antegrade slow-pathway refractoriness.\(^31\)–\(^34\), \(^9\)–\(^11\) Termination of A-V nodal re-entrant PSVT with these drugs occurs when A-V nodal re-entrant atrial responses are not followed by His bundle and ventricular responses, suggesting block in the antegrade slow pathway. The effects of these drugs on retrograde fast pathway conduction are less consistent.

In the present study, we examined the effects of procainamide in patients with dual pathway A-V nodal re-entrant PSVT. Procainamide had no statistically significant effect on either antegrade fast or slow pathway conduction. In two patients with nonsustained A-V nodal re-entrant PSVT, procainamide facilitated antegrade slow pathway
conduction, resulting in potentiation of induction of sustained PSVT. The major demonstrable effect with procainamide was the consistent depression of retrograde fast pathway conduction, as manifested by an increase in the ventricular paced cycle length producing retrograde V-A block and by an increase in retrograde fast pathway effective refractory period (when measurable). These effects could be directly related then to the effect of procainamide on induction of sustained dual pathway A-V nodal re-entrant PSVT.

In most of the patients, procainamide inhibited induction of sustained A-V nodal re-entrant PSVT. This effect directly related to depression of retrograde fast pathway conduction by this agent. In terms of PSVT induction, this depression was manifest by total loss of A-V nodal re-entrant echoes (which are dependent upon retrograde fast pathway conduction), or induction of only nonsustained PSVT, which terminated in the retrograde limb of the circus movement (retrograde fast pathway). In all of the patients who lost the ability to induce sustained PSVT after procainamide, the paced ventricular cycle length producing V-A block (retrograde block in the fast pathway) was longer than the cycle length of PSVT prior to procainamide administration. In the few patients who had induction of sustained PSVT both before and after procainamide administration, depression of retrograde fast pathway conduction was still demonstrated. However, in these patients, this depression of retrograde fast pathway conduction was not enough to interfere with sustained PSVT. In these patients, the ventricular paced cycle length producing V-A block after procainamide was less than the cycle length of sustained PSVT after this drug. It should be noted in the patients who had sustained PSVT before and after procainamide that PSVT cycle length was essentially unchanged. This reflected the lack of effect of procainamide on antegrade slow pathway conduction time and retrograde fast pathway conduction time (as compared with the effects of procainamide on retrograde fast pathway refractoriness).

The selective increase in retrograde fast pathway refractoriness seen with procainamide has not been noted before with other antiarrhythmic agents. Possible mechanisms of this depression need further discussion. If one hypothesized that the retrograde fast pathway is anatomically identical to the failed antegrade fast pathway, then procainamide exerted a unidirectional depressant effect on this pathway. Since depression of the retrograde fast pathway (as demonstrated with ventricular stimulation) was associated with spontaneous termination of PSVT, with QRS complexes not followed by atrial electrograms, the site of action of the drug would appear to be within the circus movement. For example, if procainamide depressed retrograde conduc-

tion at Purkinje–muscle junctions, or in the bundle branches, or in the distal His bundle, this would produce depression of retrograde conduction with ventricular stimulation; but this action should not interfere with ability to sustain PSVT, since the final common distal pathway of the A-V nodal circus movement has been demonstrated to be proximal to the His bundle recording site. If procainamide depressed conduction within the atrium, this might result in ventriculo-atrical block during ventricular pacing; but this action should not interfere with ability to sustain PSVT, since the final common proximal pathway should be distal to the body of atrium producing P waves on the surface electrocardio-

gram. Thus, procainamide appears to depress retrograde fast pathway conduction, distal to the proximal common pathway and proximal to the distal common pathway, suggesting that the site of action is within the A-V node.

If one hypothesized that the retrograde fast pathway was anatomically distinct from the antegrade fast pathway, then the asymmetric effect of procainamide on antegrade and retrograde fast pathway conduction could also be explained, since its effect would be exerted on tissue not utilized for antegrade conduction. It does not appear likely that the retrograde fast pathway is extranodal (free wall or septum) since none of the criteria utilized for diagnosing extranodal pathways are present in this group of patients. In addition, it has been demonstrated that retrograde fast pathway conduction (in patients with dual A-V nodal pathways) is facilitated with atropine, suggesting that the A-V node is part of the retrograde fast pathway. Our current data do not allow us to rule out the possibility that both the antegrade and/or retrograde fast pathways are atrio- nodal; however, in that case, the atrium would have to be part of the proximal common pathway, which is apparently not true.

Clinical Implications

Previous studies have suggested that the effect of acute intravenous drugs on induction of PSVT predicts the results of chronic oral drug administration. Drugs that prevent induction of sustained PSVT in patients with recurrent PSVT appear to prevent subsequent attacks. The present results thus suggest that procainamide would be an effective agent for prevention of recurrent A-V nodal re-entrant PSVT, and that this drug might be useful in converting acute attacks. In a minority of patients, the vagolytic effect of procainamide might prove deleterious, and potentiate attacks of PSVT. It also seems likely that oral quinidine might have the same result because of the similarity of these drugs. However, further studies will be necessary in order to directly relate these acute effects of intravenous procainamide on induction of A-V nodal re-entrant PSVT to subsequent clinical course.

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