A Randomized, Prospective Comparison of Anterior and Posterior Approaches to Radiofrequency Catheter Ablation of Atrioventricular Nodal Reentry Tachycardia

Jonathan J. Langberg, MD; Angel Leon, MD; Mark Borganelli, MD; Steven J. Kalbfleisch, MD; Rafel El-Atassi, MD; Hugh Calkins, MD; and Fred Morady, MD

Background. Two different techniques have been developed for radiofrequency catheter ablation of typical atrioventricular nodal reentry (AVNRT). Lesions made anteriorly near the apex of the triangle of Koch usually eliminate fast pathway function, whereas lesions made posteriorly near the ostium of the coronary sinus selectively affect slow pathway function. The current study compares the safety, efficacy, and electrophysiological effects of these two techniques in a prospective, randomized fashion.

Methods and Results. Fifty consecutive patients with typical AVNRT were randomly assigned to receive radiofrequency lesions either anteriorly (n=22) or posteriorly (n=28). If the initial approach failed to eliminate inducibility of AVNRT after 1 hour or 10 applications of radiofrequency energy, the alternative ablation technique was used. Patients underwent repeat electrophysiological testing 48 hours and 3 months after ablation. The primary success rates of the anterior and posterior techniques were similar (55% versus 68%, p=NS). All of the patients who failed the initial approach were successfully treated by the alternative technique without developing high-grade atrioventricular block. One patient developed right bundle branch block during an anterior lesion, and another patient developed complete atrioventricular block as the result of a posterior lesion.

Conclusions. The posterior approach to radiofrequency catheter modification of the atrioventricular node is as effective as the anterior approach, and both techniques are associated with a low risk of complications. As long as AVNRT persists, it appears safe to cross over from one technique to the other. (Circulation 1993;87:1551-1556)

KEY WORDS • tachycardia, supraventricular • catheters • ablation • atrioventricular node

Atrioventricular nodal reentry is the most common cause of paroxysmal supraventricular tachycardia, and typically consists of anterograde conduction via a "slow" pathway and retrograde conduction via a "fast" pathway. Two different approaches have been developed for radiofrequency catheter ablation of atrioventricular nodal reentry. Lesions made anterior to the site of the maximal His bundle electrogram, near the apex of the triangle of Koch, usually result in selective elimination of "fast" pathway function.1 In contrast, several recent studies have shown that lesions made posteriorly, near the ostium of the coronary sinus, selectively eliminate the "slow" pathway.2-5 Although prior studies have described the results of both anterior and posterior approaches to radiofrequency catheter ablation of atrioventricular nodal reentry, the optimal technique has not been defined clearly. The current study compares the safety, efficacy, and electrophysiological effects of these two techniques in a prospective, randomized fashion.

From the Department of the Internal Medicine, Division of Cardiology, University of Michigan Medical Center, Ann Arbor, Mich.
Address for correspondence: Jonathan J. Langberg, MD, University of Michigan Medical Center, 1500 E. Medical Center Drive, B1 F245, Ann Arbor, MI 48109-0022.
Received October 12, 1992; accepted January 14, 1993.

Methods

Patient Population

The study protocol was approved by the Human Research Committee at the University of Michigan, and all patients gave written consent. Fifty consecutive patients with paroxysmal supraventricular tachycardia found to be due to typical atrioventricular nodal reentry were included in the study. The subjects' mean age was 47±19 years. There were 20 women and 21 men. Patients had been symptomatic for 14±16 years and had been treated with 1.2±1.2 antiarrhythmic medications before being referred for ablation. Coronary artery disease was present in eight patients (16%), and the remaining 42 patients had no known structural heart disease.

Baseline Electrophysiology Study

Three electrode catheters were introduced into a femoral vein and positioned in the high right atrium, right ventricular apex, and across the tricuspid annulus to record the His bundle electrogram. Techniques used for the baseline electrophysiology test have been described previously.6 Incremental pacing and extrastimulation were performed in the right atrium and ventricle to define antegrade and retrograde atrioventricular nodal conduction and refractoriness and to confirm the
presence of typical atrioventricular nodal reentry. The following criteria were sought to support the diagnosis of atrioventricular nodal reentry tachycardia: 1) discontinuous atrioventricular nodal function curves, defined as an increase in the $A_H$ interval of $\geq 50$ msec with a decrement in the $A_V$ interval of 10 msec; 2) tachycardia induction associated with a critical degree of prolongation of the AH interval; and 3) atrial septal activation during tachycardia that was coincident with or closely (<50 msec) followed ventricular activation. In addition, ventricular premature beats introduced during His bundle refractoriness failed to advance the subsequent atrial activation during tachycardia, arguing against the presence of an extranodal accessory pathway. In some patients, sustained atrioventricular nodal reentry tachycardia could be induced only during an isoproterenol infusion at a rate of 2–4 μg/min.

**Apparatus Used for Ablation**

Radiofrequency energy was delivered by a power supply that produced a continuous, unmodulated output of 500 KHz (EP Technologies, Inc., Mountain View, Calif.). This device monitored, displayed, and recorded applied power and impedance during each application. Impedance rise $>300$ Ω due to coagulum formation resulted in automatic shutoff of the device.

An electrode catheter with a large distal electrode (8F in diameter and 4 mm in length) and a deflectable shaft were used to ablate the perinodal region (Mansfield Scientific, Watertown, Mass.). Radiofrequency current was applied between the distal electrode of this catheter and a large surface area adhesive skin electrode placed on the posterior chest.

**Catheter Ablation Protocol**

After confirming the presence of typical atrioventricular nodal reentry, patients were randomly assigned to undergo the anterior or posterior approach to radiofrequency ablation. Anterior sites were localized by positioning the ablation catheter at the site of the maximal His bundle electrogram and then withdrawing the catheter proximally and superiorly until the ratio of atrial to ventricular electrogram amplitudes was $\geq 1$ and the His bundle electrogram was $<40$ μV (Figure 1). Radiofrequency current was delivered at an initial output of 10 W and incremented by 2 W every 5 seconds until an effect was observed or a maximum of 30 W was applied. If junctional ectopy or an increase in the PR interval was noted, power output was held constant. During such applications, delivery was continued until there was $\geq 50\%$ increase in the PR interval or a nonconducted P wave was observed. The end point of the ablation session was a $\geq 50\%$ increase in the ventriculoatrial conduction time and/or ventriculoatrial block cycle length.

In patients randomly assigned to receive posterior lesions, the ablation catheter was introduced into the coronary sinus to define the location of the ostium. It was manipulated to sites on the tricuspid annulus adjacent to the ostium with an atrial-to-ventricular electrogram ratio of $<1$. Target sites were sought with fractionated atrial electrograms that included late components inscribed after the offset of the septal atrial electrogram and before His bundle activation (Figure 1). If target sites could not be identified near the ostium of the coronary sinus, the ablation catheter was reposi-

![Diagram of ablation catheter locations during the anterior (A) and posterior (B) approaches to radiofrequency atrioventricular nodal modification and representative target site electrograms. In this right anterior oblique projection, the tricuspid annulus is represented by a dashed line, and the atrioventricular node and specialized conduction system are represented by the shaded area. CS, ostium of the coronary sinus; RA, right atrium; RV, right ventricle. Note the presence of a diminutive His bundle potential (left arrow) at the effective site using the anterior approach (A). There is a fractionated atrial electrogram at the effective site using the posterior approach (B). Note the presence of a discrete late component of the signal (arrow), the "slow pathway potential."](http://circ.ahajournals.org/)

FIGURE 1. Diagram of ablation catheter locations during the anterior (A) and posterior (B) approaches to radiofrequency atrioventricular nodal modification and representative target site electrograms. In this right anterior oblique projection, the tricuspid annulus is represented by a dashed line, and the atrioventricular node and specialized conduction system are represented by the shaded area. CS, ostium of the coronary sinus; RA, right atrium; RV, right ventricle. Note the presence of a diminutive His bundle potential (left arrow) at the effective site using the anterior approach (A). There is a fractionated atrial electrogram at the effective site using the posterior approach (B). Note the presence of a discrete late component of the signal (arrow), the "slow pathway potential."
TABLE 1. Clinical and Baseline Electrophysiological Characteristics of Patients Randomly Assigned to Receive Anterior Versus Posterior Lesions

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Anterior approach</th>
<th>Posterior approach</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>22</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>49±20</td>
<td>46±18</td>
<td>NS</td>
</tr>
<tr>
<td>Sex (F/M)</td>
<td>11/11</td>
<td>18/10</td>
<td>NS</td>
</tr>
<tr>
<td>Coronary disease (%)</td>
<td>23</td>
<td>11</td>
<td>NS</td>
</tr>
<tr>
<td>Duration of symptoms (years)</td>
<td>14±17</td>
<td>14±17</td>
<td>NS</td>
</tr>
<tr>
<td>No. of antiarrhythmic medications</td>
<td>1.2±1.2</td>
<td>1.2±1.3</td>
<td>NS</td>
</tr>
<tr>
<td>AVBCL (msec)</td>
<td>363±71</td>
<td>354±89</td>
<td>NS</td>
</tr>
<tr>
<td>VABCL (msec)</td>
<td>346±64</td>
<td>335±90</td>
<td>NS</td>
</tr>
<tr>
<td>Dual AV nodal physiology</td>
<td>19/22</td>
<td>25/28</td>
<td>NS</td>
</tr>
<tr>
<td>AVNRT CL (msec)</td>
<td>313±56</td>
<td>340±81</td>
<td>NS</td>
</tr>
</tbody>
</table>

AVBCL, atrioventricular block cycle length; AVNRT CL, atrioventricular nodal reentrant tachycardia cycle length; VABCL, ventriculoatrial block cycle length.

If energy had been applied to 10 sites or if the ablation session had taken more than 1 hour without success in eliminating sustained atrioventricular nodal reentry, the alternative approach to ablation then was attempted. The techniques used after crossover were the same as described above.

At the conclusion of the ablation session, incremental pacing and programmed stimulation were repeated both before and during an infusion of isoproterenol sufficient to increase the sinus rate by at least 20%.

Follow-up Evaluation

The patients underwent repeat electrophysiological testing 48 hours and 3 months after successful radiofrequency catheter ablation. As before, antegrade and retrograde atrioventricular nodal conduction and refractoriness were determined both before and during isoproterenol infusion. The inducibility of atrioventricular nodal reentry tachycardia was assessed by programmed stimulation with single and double atrial extrastimuli as well as by incremental atrial overdrive pacing.

Statistical Analysis

Patients randomly assigned to receive lesions anteriorly were compared with those who had ablative energy applied posteriorly. Continuous variables were compared using Student’s t test for unpaired variables, and discrete variables were compared with χ² analysis. A value of p ≤0.05 was considered statistically significant.

Results

Among the 50 patients with typical atrioventricular nodal reentry tachycardia enrolled in the study, 22 were randomly assigned to undergo the anterior approach, and 28 were randomly assigned to undergo the posterior approach. As seen in Table 1, there was no difference in mean age, sex distribution, or prevalence of coronary artery disease between the two groups. The duration of symptoms and the number of empirical antiarrhythmic drug trials before ablation also were similar between the groups.

Table 1 also summarizes the findings at the baseline electrophysiology test. The sinus cycle length and the cycle length during typical atrioventricular nodal reentry tachycardia were not significantly different between the two groups. Antegrade and retrograde atrioventricular nodal Wenckebach cycle lengths and effective refractory periods also were comparable. Discontinuous atrioventricular nodal function curves were present in 86% of patients randomly assigned to receive posterior lesions and 82% of the patients randomly assigned to receive anterior lesions.

Primary Success Rates of the Two Techniques

Among the 22 patients randomly assigned to receive lesions anteriorly, 12 (55%) had a primary success, defined as elimination of sustained atrioventricular nodal reentry by 10 or fewer energy applications over less than 1 hour (Figure 2). One patient had chest discomfort with each radiofrequency energy application. At the patient’s request, the procedure was terminated and rescheduled for when general anesthetic could be administered. This patient was considered a primary failure of the anterior approach. The remaining nine patients were crossed over to the posterior approach. The 12 patients treated exclusively with anterior lesions had an ablation session (defined as the time from the conclusion of the diagnostic portion of the study until the hemostatic sheaths were removed at the end of the procedure) that lasted 40±38 minutes and a mean total fluoroscopy exposure of 20±14 minutes.

Nineteen of 28 patients (68%) initially treated with posterior lesions had atrioventricular nodal reentry successfully eliminated. This primary success rate was not significantly different from that achieved with the anterior approach. Ablation session duration and fluoroscopy times also were similar (37±24 and 22±10 minutes, respectively).

Overall Outcome of the Initial Session

Nine of the 22 patients randomly assigned to receive anterior lesions had persistence of atrioventricular nodal reentry tachycardia after 1 hour or 10 radiofrequency energy applications. These patients crossed over to the posterior approach, and all had a successful outcome (Figure 3). Thus, 21 of 22 patients (95%) in this cohort had a successful outcome at the end of the initial session. The mean total number of radiofrequency energy applications for the group randomized to first receive anterior lesions was 9±5. Total procedure duration was 43±32 minutes, and fluoroscopy time was 24±14 minutes.

Among the 28 patients randomly assigned to receive posterior lesions, eight crossed over to the anterior approach. All of these patients went on to be treated successfully with the anterior approach. The mean number of energy applications, procedure duration, and fluoroscopy time were not significantly different than those in the other group (9±5 applications, 44±32 minutes, and 24±11 minutes, respectively).

The overall efficacy of the anterior approach combining results both before and after crossover was 20 of 29 patients, or 70%. This was not significantly different from the combined success rate for the posterior approach (28 of 38 patients, or 78%).

Complications

One patient randomly assigned to receive posterior lesions developed persistent complete atrioventricular
block after an energy application adjacent to the ostium of the coronary sinus. The atrial-to-ventricular electrogram amplitude ratio was 1:3, and a His bundle potential was not recorded from the ablation site.

A patient randomly assigned to receive anterior lesions developed right bundle branch block because the ablation catheter inadvertently moved during an energy application. This patient went on to be successfully treated with the anterior approach without attenuation of antegrade atrioventricular conduction.

No other complications occurred. Of note was the fact that there were no complications in the 17 patients who crossed over from one approach to the other.

**Electrophysiological Effects of Anterior and Posterior Lesions**

Electrophysiological effects consistent with fast atrioventricular nodal pathway ablation were found in all 12 patients who had a primary success with the anterior approach (Figure 4). This was manifest as an increase in the AH interval and elimination or attenuation of retrograde conduction. Among the eight patients who were cured with anterior lesions after attempts at the posterior approach had failed, six had electrophysiological changes consistent with fast pathway ablation, and two had electrophysiological changes consistent with slow pathway ablation as a result of anterior lesions. Slow pathway ablation was manifest as elimination of dual atrioventricular nodal physiology and elimination of atrioventricular nodal reentry tachycardia without a change in the AH interval or retrograde ventriculoatrial conduction.

Seventeen of the 19 patients who had primary success with the posterior approach had elimination or attenuation of slow atrioventricular nodal pathway function.
Six of these 17 patients (35%) had persistent dual atrioventricular nodal physiology after successful ablation, and two (12%) had single atrioventricular nodal reentrant echoes. Nine patients crossed over to the posterior approach after failure of the anterior technique. Slow atrioventricular nodal pathway function was eliminated in seven of these patients, and fast pathway function was eliminated in two. The effective sites in all four patients who had elimination of fast pathway function during the posterior approach was in the midseptal region. These target sites were 0.5–1 cm from the site recording the maximal His bundle electrogram, and none had a visible His bundle potential.

The electrophysiological effects of fast and slow pathway ablations are compared in Table 2. The AH interval after fast pathway ablation was nearly twice that after slow pathway ablation (142±56 versus 75±19 msec, p<0.0001). There was no significant difference in the atrioventricular Wenckebach cycle length or the atrioventricular nodal effective refractory period between the two groups. One half of the patients had no ventriculoatrial conduction after fast pathway ablation, whereas all patients had intact retrograde conduction after slow pathway ablation. Those patients with persistent retrograde conduction after fast pathway ablation had a longer ventriculoatrial Wenckebach cycle length than slow pathway ablation patients (447±65 versus 300±32 msec, p<0.0001).

**Follow-up After Atrioventricular Nodal Modification**

The 50 subjects in this study have been followed for 10±2.2 months. Among the 48 patients with an initially successful outcome, 37 (77%) have had a follow-up electrophysiology test after 2.8±1.3 months. Two patients died of unrelated causes 3 and 5 months after the ablation procedure. Neither of these patients had experienced recurrent supraventricular tachycardia. The follow-up electrophysiology test documented the presence of recurrent atrioventricular nodal reentry tachycardia in five patients. Four of these patients had been randomly assigned to the anterior approach, and one was assigned to the posterior approach. The initial success was the result of fast pathway ablation in four patients, one of whom had fast pathway function eliminated with a posterior lesion. Only one patient with an initially successful slow pathway ablation had a recurrence (p=0.10).

Progressive impairment of atrioventricular conduction was not observed during follow-up. The one patient who had high-grade atrioventricular block occur after a posterior lesion was noted to have return of 1:1 atrioventricular conduction 2 months after ablation.

**Discussion**

**Main Findings**

Patients with typical atrioventricular nodal reentry tachycardia were randomly assigned to receive radiofrequency lesions anteriorly (proximal to the site of the maximal His bundle electrogram) or posteriorly (near the ostium of the coronary sinus). The results of this study were consistent with the hypothesis that the posterior approach is associated with a higher risk of recurrent tachycardia.

**TABLE 2. Electrophysiological Effects of Fast Versus Slow Atrioventricular Nodal Pathway Ablation**

<table>
<thead>
<tr>
<th></th>
<th>Fast pathway ablation</th>
<th>Slow pathway ablation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH (msec)</td>
<td>142±56</td>
<td>75±19</td>
<td>0.0001</td>
</tr>
<tr>
<td>AVBCL (msec)</td>
<td>368±55</td>
<td>343±57</td>
<td>NS</td>
</tr>
<tr>
<td>AVN ERP (msec)</td>
<td>282±61</td>
<td>280±55</td>
<td>NS</td>
</tr>
<tr>
<td>VA dissociation</td>
<td>11/22</td>
<td>0/28</td>
<td>0.0002</td>
</tr>
<tr>
<td>VABCL (msec)</td>
<td>447±65</td>
<td>300±32</td>
<td>0.0001</td>
</tr>
<tr>
<td>VAERP (msec)</td>
<td>291±76</td>
<td>238±43</td>
<td>0.03</td>
</tr>
<tr>
<td>Complete AV block</td>
<td>0/22</td>
<td>1/28</td>
<td>NS</td>
</tr>
</tbody>
</table>

AH, atrial-His interval; AVBCL, atrioventricular block cycle length; AVN ERP, atrioventricular nodal effective refractory period; VABCL, ventriculoatrial block cycle length; VAERP, ventriculoatrial effective refractory period.
study demonstrate that 1) the two techniques have similar efficacies; 2) if one approach is ineffective, switching to the other approach may be helpful; and 3) although the anterior approach usually affects fast pathway function and posterior lesions usually affect slow pathway function, posterior lesions occasionally ablate the fast pathway and vice versa.

Comparison to Previous Studies

The efficacy of the posterior approach seen in this study is consistent with the excellent results described in four recent reports.\textsuperscript{2-5} Atrioventricular nodal reentry tachycardia was eliminated with posterior lesions in 88–100\% of patients in these series. As in the current study, fast pathway function was ablated with posterior lesions in four of 34 patients described by Kay et al.\textsuperscript{2} and in one of 80 patients in the series of Jackman et al.\textsuperscript{2}

Previous reports from our laboratory\textsuperscript{1} and others have shown that the anterior approach is effective. However, this approach has been associated with a significant incidence of inadvertent complete atrioventricular block. Two factors may have contributed to the absence of atrioventricular block seen with anterior lesions in the current study. It is likely that greater operator experience decreased the likelihood of complications compared with the earlier series. In addition, a new energy delivery strategy was used during anterior ablation. Titration of radiofrequency power during each application appears to result in more gradual lesion formation and a lower risk of producing atrioventricular block.\textsuperscript{7}

Jazayeri et al.\textsuperscript{10} describe crossing over to the anterior approach in four patients after failure to ablate the slow pathway posteriorly. The fast pathway was successfully ablated in all four of these patients, but high-grade atrioventricular block developed in one patient 20 hours later.

In contrast, none of the eight patients in this study who crossed over from the posterior to the anterior approach developed atrioventricular block. Complete atrioventricular block occurred as the result of a posterior lesion in one patient in the current study. This patient had no dual atrioventricular nodal physiology or retrograde conduction in the baseline state, and atrioventricular nodal reentry could be induced only during isoproterenol infusion. These findings suggest the presence of tenuous fast pathway function and may explain the occurrence of atrioventricular block with slow pathway ablation.

Study Limitations

The experimental protocol stipulated that each approach be used for only 1 hour or 10 radiofrequency lesions before crossover. In clinical practice, it is likely that the operator would persist for a longer period of time before changing techniques. Clearly, the primary success rates in this study underestimate what could be achieved with lengthier procedures. However, the comparison between the anterior and posterior techniques was made more sensitive by limiting the duration and number of target sites used.

Clinical Implications

The posterior approach to radiofrequency catheter modification of the atrioventricular node is as effective as the anterior approach and is associated with comparable procedure durations and fluoroscopy times. Both techniques can be used with a low risk of complications. Although there was a trend toward fewer recurrences after slow pathway ablation, this did not achieve statistical significance.

Ablation of the slow atrioventricular nodal pathway posteriorly does not produce first-degree atrioventricular block. Target sites are most often several centimeters from the distal atrioventricular node, suggesting that catheter movement during energy application may be less likely to damage the distal conduction system. Despite these potential advantages, initial outcomes and short-term follow-up show that both approaches result in stable atrioventricular conduction. Further studies will be required to assess the long-term effects of the anterior and posterior approaches to atrioventricular nodal modification.

Finally, results of this study suggest that as long as atrioventricular nodal reentry tachycardia persists, it is safe to cross over from one technique to the other. Patients with tenuous conduction in one of the two limbs of the reentrant circuit constitute an infrequent exception to this recommendation. Because of the possibility of progressive effects over hours or days, patients who have transient abolition of atrioventricular nodal reentry tachycardia should not have both fast and slow pathways targeted during the same session.

References

A randomized, prospective comparison of anterior and posterior approaches to radiofrequency catheter ablation of atrioventricular nodal reentry tachycardia.

J J Langberg, A Leon, M Borganelli, S J Kalbfleisch, R el-Atassi, H Calkins and F Morady

Circulation. 1993;87:1551-1556
doi: 10.1161/01.CIR.87.5.1551

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1993 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/87/5/1551