JACC Vol. 25; No. 5
April 1995:974-81

CLINICAL STUDIES

ELECTROPHYSIOLOGY

An Anatomically and Electrogram-Guided Stepwise Approach for Effective and Safe Catheter Ablation of the Fast Pathway for Elimination of Atrioventricular Node Reentrant Tachycardia

HANS KOTTKAMP, MD, GERHARD HINDRICKS, MD, STEPHAN WILLEMS, MD, XU CHEN, MD, LUTZ REINHARDT, MSc, WILHELM HAVERKAMP, MD, GÜNTER BREITHARDT, MD, FESC, FACC, MARTIN BORGGREFE, MD

Münster, Germany

Objectives. **We describe a new stepwise anatomically and electrogram-guided strategy for radiofrequency catheter ablation of the fast pathway.**

Background. **Anatomically and electrogram-guided approaches have been developed for slow pathway ablation in patients with atrioventricular (AV) node reentrant tachycardia; however, no stepwise systematic approaches exist for fast pathway ablation.**

Methods. **Fifty-three patients (mean [±SD] age 43 ± 11 years) with AV node reentrant tachycardia underwent attempted ablation of the fast pathway. The ablation catheter was initially positioned posterior and slightly superior to the site of the maximal His bundle recording region. At these sites, the amplitude of the local atrial potential was usually at least twice as high as the local ventricular potential, and a small proximal His bundle potential was recorded. When the first pulse was ineffective, the ablation catheter was repositioned stepwise slightly inferior to more midseptal sites.**

Results. **After a mean of 3.4 ± 3.1 radiofrequency pulses (median 2, range 1 to 12), AV node reentrant tachycardia was noninducible in 51 patients (96%). No inadvertent complete AV block occurred. The AH interval was prolonged from 79 ± 19 to 145 ± 37 ms ($p < 0.001$). Thirty-eight patients (72%) developed complete ventriculoatrial block. Recording of a His bundle potential at the target site, stability of the local electrograms and occurrence of fast junctional rhythms during energy applications were more often observed at successful sites than transiently effective or noneffective sites. During a follow-up period of 12 ± 7 months, 3 (6%) of 51 patients had a clinical recurrence of AV node reentrant tachycardia.**

Conclusions. **Radiofrequency catheter ablation of the fast pathway using a combined anatomically and electrogram-guided stepwise approach is highly effective and safe. The safety of this approach seems to be due to the stable position of the ablation catheter at the interatrial septum, rather than across the tricuspid annulus, and the larger distance to the central body of the AV node and bundle of His.**

(J Am Coll Cardiol 1995;25:974-81)

In patients with recurrent symptomatic atrioventricular (AV) node reentrant tachycardia, radiofrequency catheter ablation has been established as a first-line curative treatment modality (1-3). Radiofrequency catheter-induced lesions in either the anterior tricuspid annulus region or the posteroseptal area selectively eliminate the so-called fast and slow pathways, respectively. Whereas recent investigations (3-8) described similar rates of efficacy with both modalities, there seemed to be a trend toward more unintented inductions of complete AV block when ablation of the fast pathway was attempted.

In most institutions, catheter-induced modifications of the AV node in patients with AV node reentrant tachycardia were initially performed by ablation of the fast pathway (1,3,4,6,7). The simplicity of positioning the ablation catheter in the area of the maximal His bundle recording site and performing catheter ablation after a slight withdrawal of the catheter seemed to be promising. Application of several radiofrequency pulses using this approach resulted in inadvertent complete AV block in up to 20% of patients (3). Because most investigators used fast pathway ablation during their initial attempts at catheter-induced modification of the AV node, a clear "learning curve" is likely to account for some of the unintended complete AV blocks. However, in contrast to slow pathway ablation (2,3,5), neither systematic anatomically guided nor electrogram-guided stepwise approaches have been elaborated for fast pathway ablation, thus possibly contributing to an increased risk of inadvertent complete AV block.

During our initial experience with ablation of the fast pathway (9), which was comparable to the results of other investigators (1,3,4,6,7), we used the previously described technique of positioning the ablation catheter at the site of the maximal His bundle potential and withdrawing it several

From the Department of Cardiology and Angiology, Hospital of the Westfälische Wilhelms-University and Institute for Arteriosclerosis Research, Münster, Germany.

Manuscript received January 19, 1994; revised manuscript received October 27, 1994, accepted November 9, 1994.

Address for correspondence: Dr. Hans Kottkamp, Westfälische Wilhelms-Universität Münster, Medizinische Klinik und Poliklinik, Innere Medizin C (Kardiologie und Angiologie), D-48129 Münster, Germany.

0735-1097/95/$9.50
0735-1097(94)00509-0

millimeters proximally. Thereafter, we speculated that a sequential anatomically guided strategy with an initial position posterior and slightly superior to the site of the maximal His bundle electrogram could achieve two important goals with regard to the safety of the procedure: 1) a more stable position of the ablation catheter at the interatrial septum rather than across the tricuspid annulus, and 2) greater distance to the central body of the AV node and the His bundle. After ineffective pulses, the ablation catheter was positioned stepwise to more inferior midseptal sites. This sequential approach was applied prospectively in 53 consecutive patients who underwent fast pathway ablation for elimination of AV node reentrant tachycardia at our institution. Local bipolar electrograms recorded at effective and noneffective sites were analyzed.

Methods

Patients. The study included 53 consecutive patients who underwent radiofrequency catheter ablation of the fast pathway for elimination of AV node reentrant tachycardia (mean [±SD] age 43 ± 11 years, range 23 to 62; 39 women, 14 men). The 53 patients had a mean history of tachycardia of 12 ± 11 years and had been treated with 3.0 ± 1.6 antiarrhythmic drugs that had been discontinued because of inefficacy or intolerable side effects.

Electrophysiologic study. Electrophysiologic studies were performed in the fasting, drug-free, nonsedated state after written informed consent was obtained. Multipolar catheters were introduced through sheaths inserted into the femoral vein and placed under fluoroscopic guidance in the high right atrium, His bundle region and right ventricular apex. Details of the stimulation protocol and recording technique have been described elsewhere (10). Briefly, programmed ventricular stimulation was performed from the right ventricular apex with a single premature extrastimulus and programmed atrial stimulation with up to two premature extrastimuli. Additionally, incremental ventricular and atrial pacing as well as atrial stimulation with constant cycle lengths were performed.

Sustained AV node reentrant tachycardia was induced by programmed electrical stimulation in all patients. Isoproterenol (dose titration to increase the sinus rate by 25%) was used to induce tachycardia or to convert it from nonsustained to sustained when induction could not be achieved otherwise. Patients in whom only the uncommon type of AV node reentrant tachycardia ("fast-slow") was inducible were excluded. The common variety of AV node reentrant tachycardia was identified using previously published standard criteria (11,12).

Mapping technique. A 7F quadripolar catheter with a 4-mm tip electrode (Mansfield-Webster or Cerablate Dr. Osypka, Grenzach-Wyhlen, Germany) was introduced in the right femoral vein and advanced to the septal area of the tricuspid annulus. Bipolar endocardial electrograms obtained by the ablation catheter were recorded with a filter bandwidth of 40 to 500 Hz and an amplification of 30 mm/mV. Surface electrocardiographic leads and endocardial electrograms were displayed and recorded simultaneously with a paper speed of 100 or 200 mm/s. Data were stored on a multichannel tape recorder for further evaluation.

Biplane fluoroscopy. Biplane fluoroscopy with right anterior oblique 30° and left anterior oblique 60° projections was used to determine the position of the catheters. The ablation catheter was initially positioned posterior and slightly superior to the site of the maximal His bundle recording area. At these sites, the amplitude of the local atrial potential was usually at least twice as high as the local ventricular potential, and a very proximal His bundle potential could be recorded (Fig. 1). When the amplitude of the His bundle potential exceeded that obtained in the typical His bundle region, the ablation catheter was slightly rotated clockwise and positioned more posterior. When the first pulse in this area was ineffective or no adequate potentials could be recorded, the ablation catheter was moved stepwise slightly inferior toward more midseptal sites. Typical positions of this approach are illustrated in Figure 2 and a schematic drawing is shown in Figure 3.

Electrogram analysis. Local endocardial electrograms of 5 consecutive beats preceding the application of radiofrequency current were analyzed. Electrograms were categorized according to the effects of energy application into effective, transiently effective and noneffective sites. A *transient effect* was defined as prolongation of the atrial–His bundle interval or slowing of ventriculoatrial (VA) conduction and noninducibility of AV node reentrant tachycardia with resumption within the ablation session. The local bipolar electrograms were analyzed for the presence and amplitude of a His bundle potential, the atrial/ventricular potential amplitude ratio and stability. Electrograms were considered *unstable* if the amplitude of the atrial, ventricular or His bundle potential changed by >10%, a deflection of a local potential disappeared or a new deflection appeared. In patients with short atrial–His bundle intervals, the presence of a His bundle potential in the electrogram obtained by the ablation catheter positioned in the previously described area in some cases could not be assessed during sinus rhythm. A typical example is depicted in Figure 4. During sinus rhythm, no His bundle potential could be detected. However, the His bundle potential obtained by the catheter placed in His bundle position coincided with the end of the atrial potential obtained by the ablation catheter that obscured the His bundle potential. During stimulation with extrastimuli or constant rate pacing, the atrial–His bundle interval prolonged, and the presence of a clear His bundle potential recorded by the ablation catheter was unmasked. In some cases, stimulation revealed His bundle potentials larger or at least of equal amplitude to the His bundle potentials obtained by the catheter in typical His bundle position. In these cases, the ablation catheter was repositioned to a slightly more posterior site. The occurrence of junctional ectopic rhythms during energy application was analyzed for each radiofrequency pulse by continuously monitoring and recording the electrocardiogram during current delivery. However, during junctional ectopic activity, the integrity of anterograde

JACC Vol. 25; No. 5 April 1995:974–81

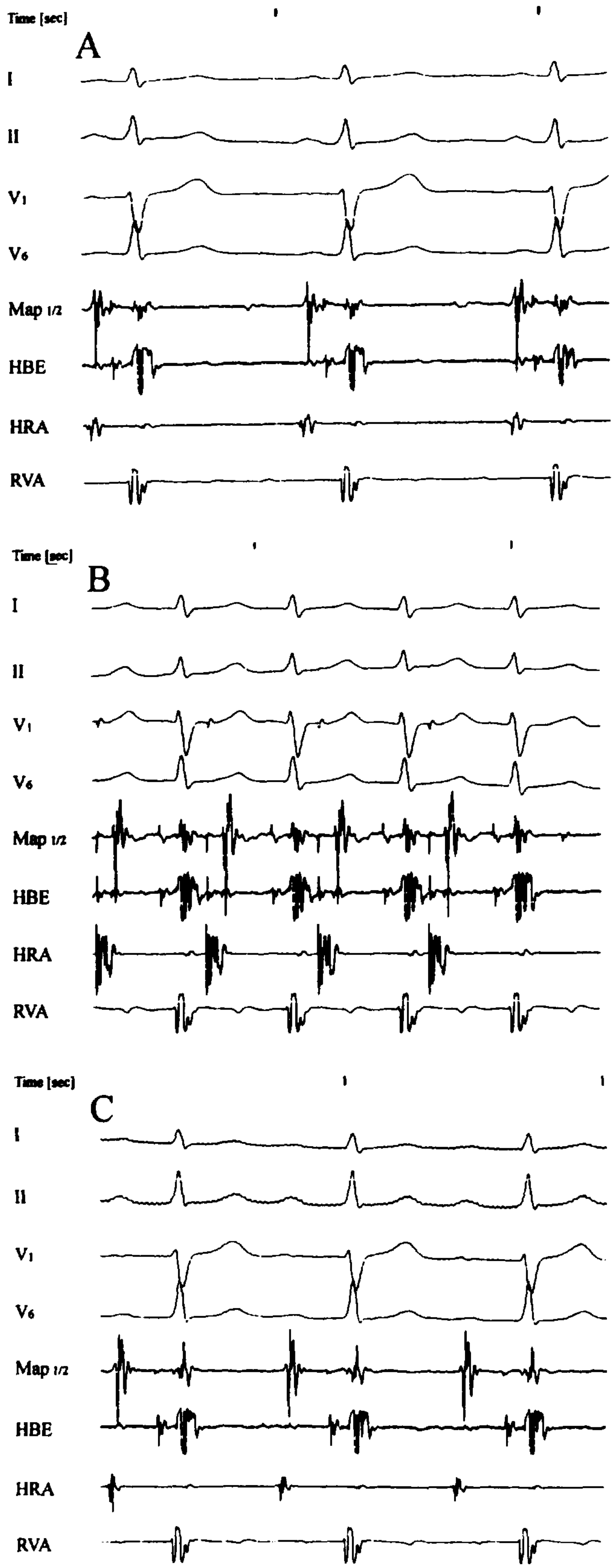

Figure 1. Simultaneous recordings of surface leads I, II, V_1 and V_6 and intracardiac recordings of the distal pair of electrodes of the ablation catheter (Map 1/2), His bundle region (HBE), high right atrium (HRA) and right ventricular apex (RVA). **A and B,** Recordings during sinus rhythm and atrial stimulation at the high right atrium (cycle length 430 ms) for a representative target site electrogram. The ablation catheter was positioned posterior to the site of maximal His bundle recording by clockwise rotation of the catheter (same patient as in Fig. 2, A and B). A proximal His bundle potential and an atrial/ventricular potential amplitude ratio of 3.6 was obtained in this position. **C,** Application of radiofrequency current at this site resulted in an increase of the atrial–His bundle interval from 90 to 170 ms, indicating successful ablation of the fast pathway.

AV conduction in some instances cannot be assessed with certainty. Additionally, fast junctional tachycardia during energy delivery has been identified as heralding complete AV block (13). Therefore, radiofrequency current in this study was only applied during constant rate pacing at the high right atrium with cycle lengths of 500 to 400 ms. When fast junctional ectopic rhythms of shorter cycle lengths than the pacing cycle length occurred, the pacing rate was immediately accelerated until 1:1 AV conduction was achieved. Otherwise, radiofrequency application was immediately interrupted. Energy delivery was also stopped when sudden increases in impedance occurred. The catheter was then withdrawn and controlled for adherent coagulated material. Additionally, current application was immediately interrupted when Wenckebach periodicity or AV block occurred. After each radiofrequency pulse, ventricular stimulation was performed for assessment of retrograde conduction.

Ablation end points. The end points of the ablation session were an increase of the atrial–His bundle interval of >50% or elimination or marked slowing of VA conduction, or both, and the noninducibility of AV node reentrant tachycardia before and during isoproterenol infusion.

Radiofrequency current application. Radiofrequency alternating current was administered using a continuous sinusoidal unmodulated waveform of 500 kHz (HAT 200S, Dr. Osypka GmbH). Energy was delivered in an unipolar mode between the tip electrode of the ablation catheter and a 10 × 16-cm external backplate electrode. In the first 22 patients, the preselected power output was 15 to 50 W, and the preset time ranged from 60 to 90 s. In the following 31 patients, a temperature-guided energy application was used. In 15 patients, the preselected temperature was 60° to 70°C, and the radiofrequency generator delivered energy as a function of actual catheter tip–tissue interface temperature. In the other 16 patients, a sequential temperature-titrated approach was used. The preselected temperature for these 16 patients was 45° to 50°C and was upregulated in five to 10°C steps after every 10 to 15 s if no prolongation of the atrial–His bundle interval was noted up to a maximal temperature of 80°C. The preset time during temperature-guided current application also ranged from 60 to 90 s.

Follow-up. The patients underwent predischarge electrophysiologic testing 2 to 4 days and 6 months after the ablation

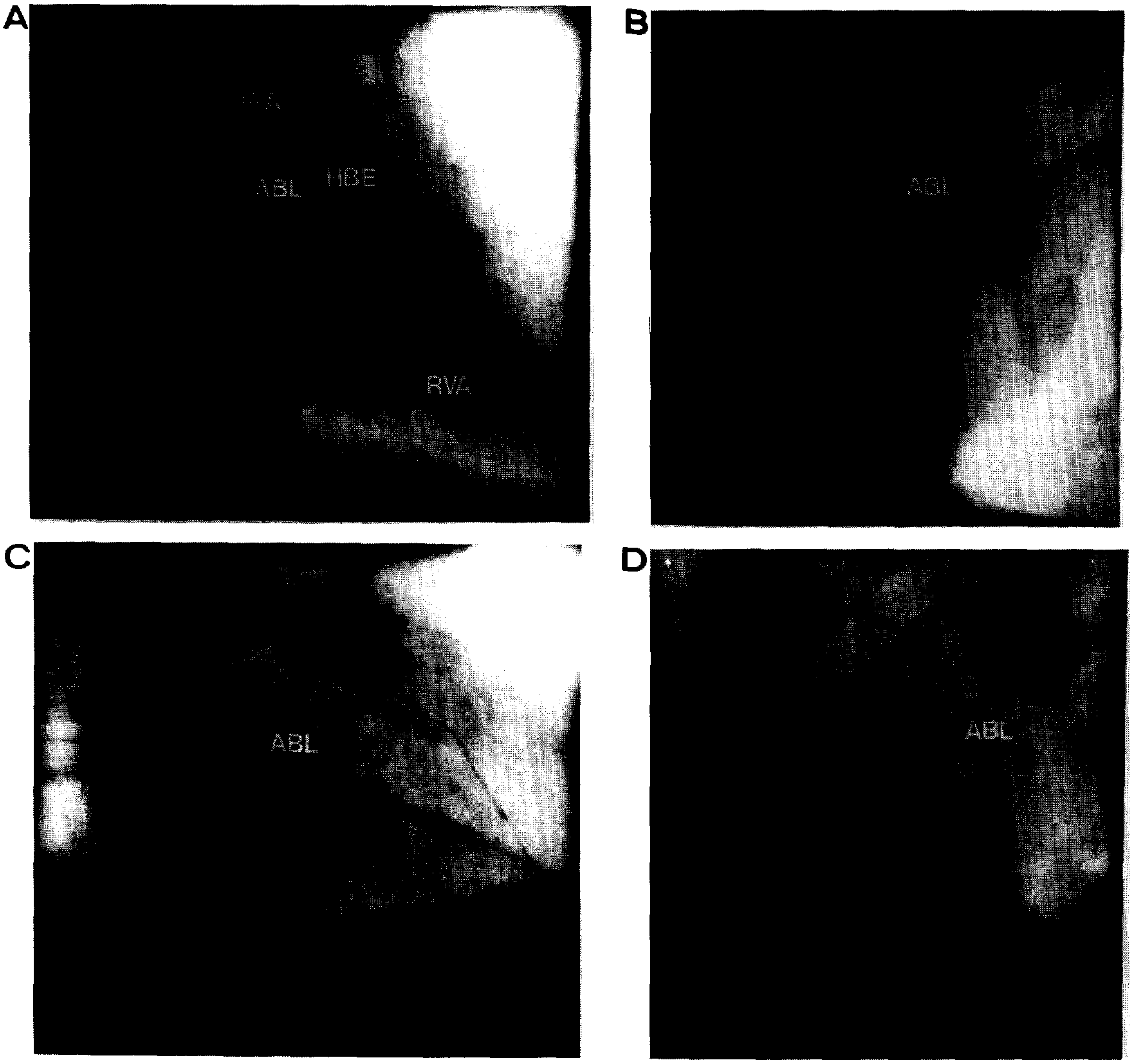

Figure 2. Radiograms in right anterior oblique 30° (**A and C**) and left anterior oblique 60° (**B and D**) projections presenting two different locations of the ablation catheter (ABL). Additionally, catheters were placed in the high right atrium (HRA), right ventricular apex (RVA) and His bundle region (HBE). **A and B,** The ablation catheter was positioned posterior to the site of typical His bundle recording by clockwise rotation of the catheter. **C and D,** The ablation catheter was positioned posterior and slightly inferior to the site of maximal His bundle recording. These catheter placements represent examples of areas depicted schematically in Figure 3, B and C.

session. The ablation procedure was considered successful when AV node reentrant tachycardia was noninducible before and during isoproterenol infusion (titrated to increase the sinus rate by 25%).

Statistical analysis. Continuous variables are expressed as mean value ±SD. Continuous variables before and directly after radiofrequency ablation were compared by the Student *t* test or Mann-Whitney *U* test when appropriate. Additionally, repeated measures analysis of variance followed by multiple comparison was used for comparison between the data in the four measurements groups (baseline, after ablation, before discharge, after 6 months). Discrete variables were compared using chi-square analysis. The Statistical Package for the Social Science Program (SPSS for Windows, SPSS, Inc.) was used for computer analysis; $p < 0.05$ was considered significant.

Results

Sustained AV node reentrant tachycardia of the common type was inducible during the baseline study (n = 38) or during isoproterenol infusion (n = 15) in all 53 patients. Mean tachycardia cycle length was 319 ± 83 ms. The patients received 3.4 ± 3.1 (median 2, range 1 to 12) radiofrequency pulses. Mean fluoroscopy time was 26 ± 16 min. Atrioventricular node reentrant tachycardia was rendered noninducible in 51 (96%) of 53 patients at the end of the ablation session. In no patient was inadvertent complete AV block induced. Patients with an unsuccessful outcome underwent effective slow path-

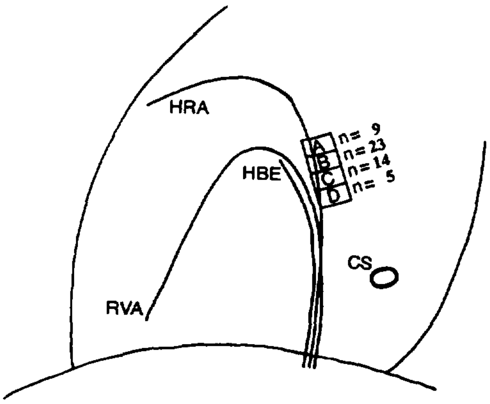

Figure 3. Schematic drawing of a radiogram in the left anterior oblique 60° projection. Catheters are placed in the high right atrium (HRA), right ventricular apex (RVA) and His bundle region (HBE). Posterior target site areas for sequential application of radiofrequency energy from superior to inferior are labeled A to D. Successful current applications for ablation of fast pathway conduction were obtained in 9 cases in **area A,** 23 in **area B,** 14 in **area C** and 5 in **area D,** respectively. CS = coronary sinus ostium. See text for further explanation.

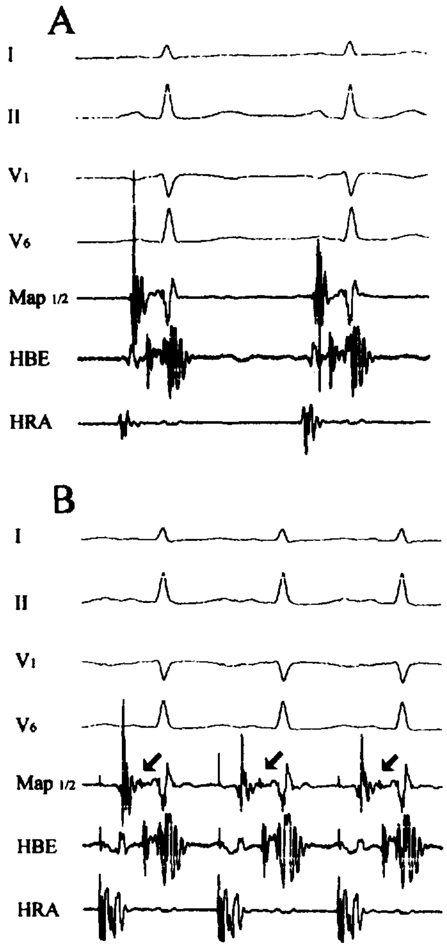

Figure 4. Simultaneous recordings of surface leads I, II, V_1 and V_6 and intracardiac recordings of the distal pair of electrodes of the ablation catheter (Map 1/2), His bundle region (HBE) and high right atrium (HRA). **A,** Recordings during sinus rhythm. Local electrogram obtained by the ablation catheter showed an atrial and ventricular potential without a His bundle potential. However, the His bundle potential recorded by the catheter placed in the His bundle region coincided with the end of the atrial potential obtained by the ablation catheter that obscured the His bundle potential. **B,** During atrial stimulation at the high right atrium (cycle length 370 ms), the atrial–His bundle interval prolonged from 65 to 100 ms, thereby unmasking the recording of a proximal His bundle potential obtained by the ablation catheter. Stability of the catheter was indicated by the similar configuration of the local electrograms during sinus rhythm and atrial stimulation. At this site, the fast pathway was successfully ablated.

way ablation in a second ablation session. No procedural complications occurred.

Early results. The effects of radiofrequency catheter ablation on electrophysiologic variables are summarized in Table 1. The PR and AH intervals were prolonged from 151 ± 23 and 79 ± 19 ms to 221 ± 36 ($p < 0.001$) and 145 ± 37 ms ($p < 0.001$), respectively. No significant differences were observed in the HV interval (44 ± 7 vs. 43 ± 7 ms, p = NS) and in the longest cycle length during atrial pacing at which Wenckebach block occurred (296 ± 53 vs. 287 ± 59 ms, p = NS). Thirty-eight (72%) of the 53 patients had complete VA block after ablation, and only 6 of 40 patients continued to reveal an increase in the A_2H_2 intervals >50 ms in response to a 10-ms decrement in the A_1A_2 interval during application of premature atrial extrastimuli (AH jump). In the 15 patients with persistent VA conduction, the longest cycle length during ventricular pacing at which VA dissociation occurred was prolonged from 295 ± 49 to 424 ± 86 ms ($p < 0.001$). The effective pulses were applied to areas A through D in 9, 23, 14 and 5 cases, respectively (fig. 3).

A total of 196 local electrograms were analyzed immediately before delivery of radiofrequency current. Of these, 51 were effective, 34 were transiently effective, and 111 were noneffective. The absolute and percent prolongation of the atrial–His interval was significantly larger for effective than transiently effective pulses (71 ± 35 vs. 41 ± 20 ms, $p < 0.001$ and 84 ± 52% vs. 52 ± 34%, $p < 0.01$, respectively). The atrial–His bundle interval in patients in whom no His bundle potential was recorded with the ablation catheter at the effective site during sinus rhythm, but which was visible during atrial stimulation (n = 10) (Fig. 4), was significantly shorter than that in patients in whom a His bundle potential was visible during sinus rhythm (n = 31) (65 ± 12 vs. 91 ± 17 ms, $p < 0.001$).

A His bundle potential could be recorded at 41 (80%) of 51 effective sites and at 69 (48%) of 145 transiently effective or noneffective sites ($p < 0.005$). The amplitude of the His bundle potential did not differ significantly among effective and transiently effective or noneffective sites (89 ± 43 vs. 72 ± 39 μV, p = NS). The local bipolar electrogram was stable at 43 (84%) of 51 effective sites and at 77 (53%) of 145 transiently effective or noneffective sites ($p < 0.005$). Ectopic junctional rhythms during radiofrequency current application occurred at 34 (67%) of 51 effective sites and at 47 (32%) of 145 transiently

Table 1. Effects of Radiofrequency Catheter Ablation on Electrophysiologic Variables

	Baseline (n = 53)	After Ablation (n = 53)	Before Discharge (n = 51)	After 6 mo (n = 31)
PR (ms)*	151 ± 23	221 ± 36	224 ± 37	211 ± 29
AH (ms)*	79 ± 19	145 ± 37	159 ± 39	144 ± 38
HV (ms)†	44 ± 7	43 ± 7	44 ± 6	45 ± 8
AVN-BCL (ms)†	296 ± 53	287 ± 59	306 ± 61	311 ± 54
VA-BCL (ms)*	288 ± 41	424 ± 86	435 ± 88	393 ± 91
VA block	0 (0%)	38 (75%)	38 (75%)	23 (74%)
AH jump	40 (75%)	6 (11%)	6 (12%)	3 (10%)

*Repeated measures analysis of variance with multiple comparison; significant differences were observed between measurement groups. †Repeated measures analysis of variance with multiple comparison; no significant differences were observed between measurement groups. Data presented are mean value ± SD or number (%) of patients. AVN-BCL = longest cycle length during atrial pacing at which Wenckebach block occurred; VA-BCL = longest cycle length during ventricular pacing at which ventriculoatrial dissociation occurred; VA-block = number of patients with complete ventriculoatrial dissociation at the longest captured ventricular cycle length; AH-jump = increase in the A_2H_2 intervals >50 ms in response to a 10-ms decrement in the A_1A_2 interval during application of premature atrial extrastimuli.

effective or noneffective sites ($p < 0.001$). The atrial/ventricular potential amplitude ratio did not differ among effective and transiently effective or noneffective sites (4.8 ± 3.6 vs. 4.5 ± 3.8, p = NS).

Radiofrequency pulses applied with a constant power output (n = 84) had a duration of 31 ± 20 s, a mean power of 27 ± 10 W and a cumulative energy of 824 ± 490 J. Temperature-guided radiofrequency pulses (n = 112) had a duration of 48 ± 23 s, a mean power of 12 ± 13 W and a cumulative energy of 421 ± 196 J. Sudden increases in impedance occurred during 11 (13%) of 84 applications with constant power output and in 3 (3%) of 112 applications with temperature-guided power output. Examples of the recordings of power, impedance and catheter tip temperature during temperature-guided radiofrequency current application are depicted in Figure 5. The preselected temperature was reached in 74 (80%) of 93 energy

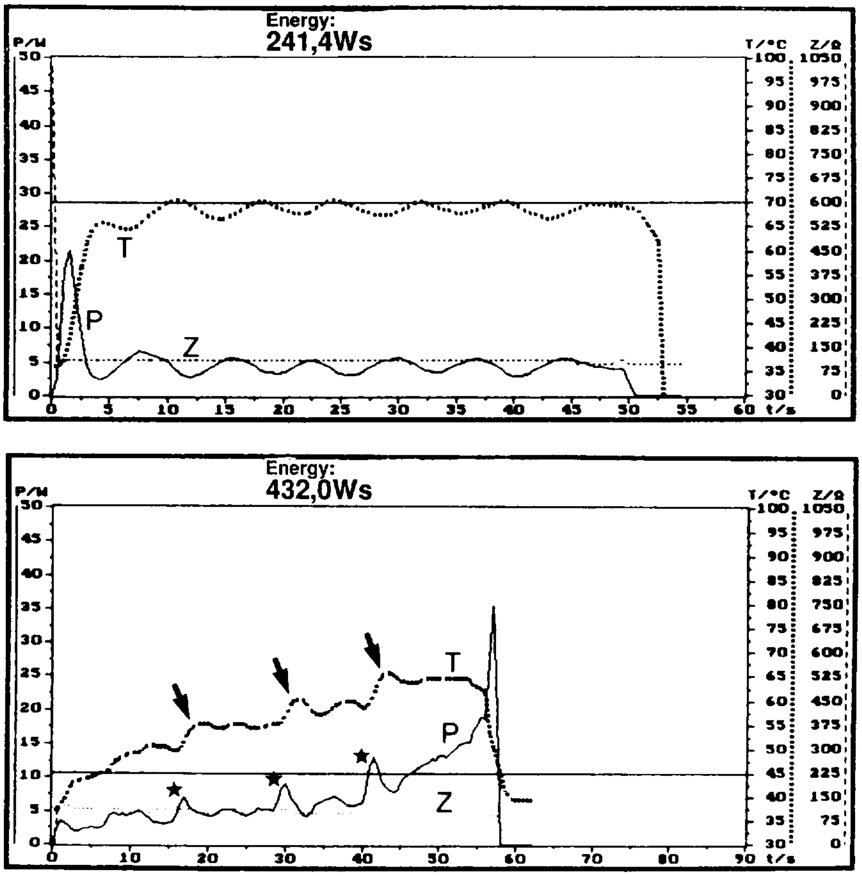

Figure 5. Simultaneous recordings of catheter tip–tissue interface temperature (T), power output (P) and impedance (Z) during radiofrequency current application in two patients who underwent catheter ablation of the fast pathway for elimination of atrioventricular node reentrant tachycardia. **A,** Recordings during a current application guided by a constant preselected temperature of 70°C. Note, an initial peak of applied power (22 W) resulted in a temperature increase to the preselected level, and only 5 W were sufficient for maintenance of the temperature, resulting in a cumulative applied energy of only 241.4 J. After 25 s there was an increase in the atrial–His interval, indicating successful fast pathway ablation. **B,** Recording during a sequentially titrated temperature-guided application of radiofrequency current. After 15, 30 and 40 s, respectively, preselected temperature was upregulated **(arrows)**. Note that each increase in catheter tip–tissue interface temperature was preceded by a new peak in applied power **(stars)**, resulting in a cumulative energy of 432.0 J. After 45 s there was an increase in the atrial–His interval. Note, after 57 s catheter displacement occurred, resulting in an abrupt decrease in catheter tip–tissue interface temperature with a concomitant increase in power output. At this point, the current application was immediately terminated.

applications with stable local electrograms but only in 5 (26%) of 19 applications with unstable local electrograms.

Early restudy. The effects of radiofrequency catheter ablation were restudied 2 to 4 days after the ablation session before discharge (Table 1). None of the initially successfully treated 51 patients had spontaneous or inducible common AV node reentrant tachycardia. In three patients without symptomatic arrhythmias, the uncommon type of AV node reentrant tachycardia was inducible during isoproterenol infusion.

Follow-up and late restudy. After an average of 12 ± 7 months, 3 (6%) of 51 patients had a symptomatic recurrence of AV node reentrant tachycardia. Thirty-one of the 51 initially successfully treated patients underwent electrophysiologic studies 6 months after the ablation session (Table 1). Atrioventricular node reentrant tachycardia was inducible in all three patients with a clinical recurrence. These patients underwent a second successful ablation (fast pathway ablation in two, slow pathway ablation in one). Patients with the inducible uncommon type of AV node reentrant tachycardia at early restudy remained free of symptomatic arrhythmias without treatment.

Discussion

Main findings. The results of the present study indicate that radiofrequency energy application using a new combined anatomically and electrogram-guided stepwise approach for ablation of the fast pathway for definitive cure of AV node reentrant tachycardia is highly effective and safe. With a median of two pulses, 51 (96%) of 53 patients had noninducible tachycardia at the end of the ablation session. Additionally, inadvertent complete AV block did not occur in any patient. The safety of this approach may be due to the stable position of the ablation catheter at the interatrial septum rather than across the tricuspid annulus and the larger distance from the ablation sites to the central body of the AV node and bundle of His.

Comparison with previous studies. Modification of the AV node for treatment of AV node reentrant tachycardia was initially performed by ablation of the fast pathway, the so-called anterior approach (1,3,4,6,7). Using this technique, the catheter was initially positioned at the site of maximal His bundle potential recording and ablation performed after slight withdrawal of the catheter. Usually, criteria for target sites included only the recording of a very small His bundle potential amplitude and an atrial/ventricular electrogram amplitude ratio >1. Jazayeri et al. (3) reported that unintentional AV block occurred in 4 of 19 patients who underwent fast pathway ablation. Detailed analysis of the local electrograms in these patients revealed shorter A_H–A_{CS} intervals, defined as the interval from the onset of local atrial deflection in the His bundle electrogram to the onset of local atrial deflection in the proximal coronary sinus adjacent to the coronary sinus ostium during AV node reentrant tachycardia or ventricular pacing, than in patients without complete AV block. Jazayeri et al. (3) suggested that, at least in this subgroup of patients, the fast pathway might be situated toward the posterior portion of the interatrial septum rather than in an anterior location. Using the so-called anterior approach, a stable position of the ablation catheter is difficult to achieve, especially during atrial or ventricular extrasystoles and junctional rhythms. Additionally, this position is in close vicinity to the central body of the AV node, and slight displacement during radiofrequency current application could account for inadvertent complete AV block. We therefore hypothesized that a sequential anatomically guided strategy with an initial position posterior and slightly superior to the site of the maximal His bundle electrogram could achieve two important goals with regard to the safety of the procedure: 1) a more stable position of the ablation catheter at the interatrial septum rather than across the tricuspid annulus, and 2) greater distance to the central body of the AV node and the lower common pathway. The rationale for the efficacy of this stepwise approach is supported by a study from Keim et al. (14) using intraoperative ice mapping during AV node reentrant tachycardia. These investigators observed that termination of the tachycardia due to block in the fast pathway could be achieved on an array of mapping points from peripheral to more central points. Our approach of application of radiofrequency energy using a stepwise strategy from the periphery (i.e., posterior superior to the site of maximal His bundle recording) to the center (i.e., more inferior to midseptal sides of the interatrial septum) confirmed the results of the intraoperative mapping study with respect to efficacy and safety because a substantial number of fast pathways could be ablated at peripheral posterior sites.

Electrogram criteria for successful fast pathway ablation. Local bipolar electrograms of effective, transiently effective and noneffective sites were analyzed for the presence and amplitude of a His bundle potential at the target site, atrial/ventricular potential amplitude ratio and stability of the ablation catheter. Additionally, the occurrence of junctional rhythms during energy application was determined. Although His bundle potentials and junctional rhythms during energy application were significantly more often observed at effective than transiently effective or noneffective sites, the amplitude of the His bundle potential and the atrial/ventricular potential amplitude ratio did not differ significantly between these two groups. Therefore, fast pathway ablation using our stepwise approach to a substantial proportion is anatomically guided. Of note, bipolar electrograms obtained at the posterior portion of the interatrial septum in patients with short atrial–His bundle intervals may obscure the recording of His bundle potentials (Fig. 4). Therefore, atrial pacing with extrastimuli or constant rate pacing with resulting prolongation of the atrial–His bundle intervals seems mandatory for identification of the presence and amplitude of His bundle potentials at target sites. In contrast to slow junctional rhythm, fast junctional tachycardia during energy application for modification of the AV node has been demonstrated to herald complete AV block (13). In the present study, the pacing rate during energy delivery was therefore immediately accelerated until 1:1 AV conduction was achieved when fast junctional tachycardia occurred.

Fast versus slow pathway ablation. Whereas similar results with respect to the efficacy of fast versus slow pathway ablation have been reported, several investigators reported a higher incidence of inadvertent complete AV block when fast pathway ablation was attempted (3,6–8). However, in these institutions, catheter-induced modification of the AV node was initially performed attempting fast pathway ablation, and a "learning curve" could in part account for the more favorable outcome of slow pathway ablation. To our knowledge, only one randomized, prospective comparison of fast and slow pathway ablation presently exists (15). That study, performed in a highly experienced institution, reported no differences with respect to efficacy and safety of both approaches. Additionally, in contrast to slow pathway ablation, where systematic approaches with "slow pathway potentials" (2,5) or anatomically guided stepwise approaches (3) are used, no systematic stepwise strategies have thus far been elaborated for fast pathway ablation. The results of the present study suggest that a combined anatomically and electrogram-guided stepwise strategy for ablation of the fast pathway in the posterior portion of the interatrial septum from superior to midseptum may contribute to reducing the risk of inadvertent complete AV block while maintaining excellent efficacy. Recently, Langberg et al. (16) introduced an approach with titration of power output during radiofrequency catheter ablation of the fast pathway, thereby reducing the risk of complete AV block. A combination of this approach with the strategy described in our study might result in even safer and more effective ablation of the fast pathway. In 31 of our patients, a temperature-guided mode using a constant preselected temperature or a sequential temperature-titrated approach was applied. Radiofrequency pulses in these patients revealed a substantially lower cumulative energy and mean power than applications with a constant power output. Additionally, a sudden increase in impedance occurred more often during applications with a constant power output than with temperature-guided applications. However, the mode of energy application was not randomized in the present study. Therefore, the impact of temperature-guided application of radiofrequency energy on the efficacy-risk profile of fast pathway ablation needs to be determined in a prospective randomized study.

Limitations of the study. The present study is based on results in 53 patients. Although the strategy described in this report revealed an excellent efficacy with a low number of radiofrequency pulses without induction of inadvertent complete AV block, a larger series would be desirable for confirmation of our results with particular respect to long-term follow-up. Although the only prospective, randomized study comparing fast and slow pathway ablation (15) to date revealed no differences with respect to efficacy and safety, slow pathway ablation might be identified as the first-line approach for treatment of AV node reentrant tachycardia in ongoing studies with larger numbers of patients. In the Multicenter European Radiofrequency Survey (8), the incidence of complete AV block was significantly higher for fast than slow pathway ablation. Consequently, slow pathway ablation should be considered the first approach. However, fast pathway ablation may be necessary in patients in whom attempted slow pathway ablation failed as well as in those in whom AV node reentrant tachycardia is not reproducibly inducible and in whom ablation success therefore cannot be assessed with certainty after attempted slow pathway ablation. In addition, there is at present no definite answer as to whether fast or slow pathway ablation is superior with respect to long-term follow-up.

References

1. Calkins H, Sousa J, El-Atassi R, et al. Diagnosis and cure of the Wolff-Parkinson-White syndrome or paroxysmal supraventricular tachycardias during a single electrophysiologic test. N Engl J Med 1991;324:1612–8.
2. Jackman WM, Beckman KJ, McClelland JH, et al. Treatment of supraventricular tachycardia due to atrioventricular nodal reentry by radiofrequency catheter ablation of slow-pathway conduction. N Engl J Med 1992;327:313–8.
3. Jazayeri MR, Hempe SL, Sra JS, et al. Selective transcatheter ablation of the fast and slow pathways using radiofrequency energy in patients with atrioventricular nodal reentrant tachycardia. Circulation 1992;85:1318–1328.
4. Lee MA, Morady F, Kadish A, et al. Catheter modification of the atrioventricular junction with radiofrequency energy for control of atrioventricular nodal reentry tachycardia. Circulation 1991;83:827–35.
5. Haissaguerre M, Gaita F, Fischer B, et al. Elimination of atrioventricular nodal reentrant tachycardia using discrete slow potentials to guide application of radiofrequency energy. Circulation 1992;85:2162–75.
6. Mitrani PD, Klein LS, Hackett FK, Zipes DP, Miles WM. Radiofrequency ablation for atrioventricular node reentrant tachycardia: Comparison between fast (anterior) and slow (posterior) pathway ablation. J Am Coll Cardiol 1993;21:432–41.
7. Chen SA, Chiang CE, Tsang WP, et al. Selective radiofrequency catheter ablation of fast and slow pathways in 100 patients with atrioventricular nodal reentrant tachycardia. Am Heart J 1993;125:1–10.
8. Hindricks G. On behalf of the Multicenter European Radiofrequency Survey (MERFS) Investigators: the Multicenter European Radiofrequency Survey (MERFS)—Complications of radiofrequency catheter ablation of arrhythmias. Eur Heart J 1993;14:1644–53.
9. Willems S, Chen X, Hindricks G, et al. Radiofrequency ablation of AV-nodal reentry tachycardia: Experience with selective fast pathway ablation. Z Kardiol, 1994;83:165–72.
10. Chen X, Borggrefe M, Shenasa M, Haverkamp W, Hindricks G, Breithardt, G. Characteristics of local electrogram predicting successful transcatheter radiofrequency ablation of left-sided accessory pathways. J Am Coll Cardiol 1992;20:656–65.
11. Akhtar M. Paroxysmal atrioventricular nodal reentrant tachycardia. In: Narula, OS, editor. Cardiac Arrhythmias: Electrophysiology, Diagnosis, and Management. Baltimore: Williams & Wilkins, 1979:294–316.
12. Brugada P, Wellens, HJJ. Electrophysiology, mechanisms, diagnosis, and treatment of paroxysmal recurrent atrioventricular nodal reentrant tachycardia. In: Surawicz B, Reddy CP, Prystowsky, EN, editors. The Tachycardias. Boston: Martinus Nijhoff, 1984:131–57.
13. Thakur RK, Klein GJ, Yee R, Stites, HW. Junctional tachycardia: a useful marker during radiofrequency ablation for atrioventricular node reentrant tachycardia. J Am Coll Cardiol 1993;22:1706–10.
14. Keim S, Werner P, Jazayeri M, Akhtar M, Tchou, P. Localization of the fast and slow pathways in atrioventricular nodal reentrant tachycardia by intraoperative ice mapping. Circulation 1992;86:919–25.
15. Langberg JJ, Leon A, Borganelli M, et al. A randomized, prospective comparison of anterior and posterior approaches to radiofrequency catheter ablation of atrioventricular nodal reentry tachycardia. Circulation 1993;87:1551–6.
16. Langberg JJ, Harvey M, Calkins H, El-Atassi R, Kalbfleisch SJ, Morady F. Titration of power output during radiofrequency catheter ablation of atrioventricular nodal reentrant tachycardia. PACE 1993;16:465–70.