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Is Electrical Stimulation During Administration of Catecholamines Required for the Evaluation of Success After Ablation of Atrioventricular Node Re-entrant Tachycardias?

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OBJECTIVES The purpose of this study was to answer the question of whether stimulation after administration of catecholamines is mandatory for identifying unsuccessful ablations of atrioventricular node re-entrant tachycardia (AVNRT).

BACKGROUND The success of radiofrequency (RF) catheter ablation in AVNRT is confirmed in many centers by noninducibility of tachycardias during stimulation after the administration of catecholamines.

METHODS A total of 131 patients (81 women and 50 men; mean age 53.6 ± 13.7 years [range 20 to 77]) were studied. Electrical stimulation was performed without and with the beta-adrenergic amine Orciprenaline (metaproterenol) before and after RF catheter ablation.

RESULTS In 100 patients (76.3%; confidence interval [CI] 68.1% to 83.3%) an AVNRT was inducible without administration of Orciprenaline. Thirty minutes after the initially successful ablation in 95 patients, tachycardia was inducible in none of these patients, not even after Orciprenaline administration. In the 31 patients (23.7%; CI 16.7% to 31.9%) in whom there was no tachycardia inducible before ablation, Orciprenaline was given, and the stimulation protocol was repeated. In only five patients (3.8%; CI 1.3% to 8.7%) was there still no tachycardia inducible. After an initially successful ablation in the 26 patients who had inducible tachycardias with Orciprenaline before ablation, no tachycardia could be re-induced. After Orciprenaline, the tachycardia was inducible again in only one patient.

CONCLUSIONS Only patients who require catecholamines for tachycardia induction before ablation need catecholamines for control of the success of the ablation of AVNRT. (J Am Coll Cardiol 2002;39:689–94) © 2002 by the American College of Cardiology

Radiofrequency (RF) catheter ablation of atrioventricular node re-entrant tachycardia (AVNRT) by modulation or ablation of slowly conducting atrioventricular (AV) nodal pathways is a routine procedure in cardiology centers (1). For many authors, successful ablation of AVNRT is proven only by noninducibility of the tachycardia after administration of catecholamines (2–7). Isoproterenol, the most potent sympathomimetic amine, which acts almost exclusively on beta-receptors, was widely used for this purpose in the U.S. up to now (8). Orciprenaline (metaproterenol; Alupent, Boehringer Ingelheim, Ingelheim, Germany) is widely used for this administration in Germany. It is a beta-receptor agonist that is similar to isoproterenol (8). The purpose of this study was to answer the question of whether an additional electrical stimulation after administration of a beta-adrenergic agonist, after a primarily successful ablation of AVNRT, is required.

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METHODS

Study group. In the present study, 131 consecutive patients (50 men and 81 women) with AVNRT were included. All patients complained of a paroxysmal, rapid heart rate. In most patients, a regular tachycardia was documented by electrocardiography (12-lead, Holter monitoring). The mean age of the patients was 53.5 ± 13.7 years (range 20 to 77). In 26 patients, a structural cardiac disease was present. Twenty patients had coronary artery disease; three patients had dilated cardiomyopathy; one patient had coronary artery disease and a moderate aortic stenosis; one patient had a cor pulmonale due to structural lung disease; and one patient had an atrial septal defect that had previously been closed. One hundred five patients had no signs of structural heart disease, as detected by electrocardiography, transthoracic echocardiography, treadmill testing, and coronary angiography in men older than 39 years and in women older than 44 years.

Electrophysiologic diagnostic procedure. On the day before the procedure, all patients gave written, informed consent to undergo the intended electrophysiologic study and ablation. For sedation and analgesia, 5 mg of diazepam

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Abbreviations and Acronyms

AH = A2-H2 interval
AV = atrioventricular
AVNRT = atrioventricular node re-entrant tachycardia
CI = confidence interval
ECG = electrocardiogram or electrocardiographic
RF = radiofrequency

and 5 mg of morphine sulfate were given intravenously. All anti-arrhythmic drugs were stopped earlier than five half-lives before the procedure. The ablation was performed after a bolus injection of 5,000 IU of heparin. Two 4-pole, 6F electrode catheters (Bard, Billerica, Massachusetts), with a 5-mm interelectrode distance, were introduced over the femoral veins and placed in the right atrial appendage and at the His bundle. The tip of a bipole, 5F electrode catheter (Cordis, Watertown, Massachusetts) was placed in the apex of the right ventricle through a femoral vein.

Another electrode catheter with 10 poles and an interelectrode distance of 2 mm (Bard) was inserted into the proximal coronary sinus through the left antecubital vein or the right internal jugular vein. All 12-surface electrocardiographic (ECG) leads were stored with the intracardiac electrograms, using a multi-channel recording system (Bard, LabSystems version 2.57/2.58), and stored on an optical disk.

Programmed electrical stimulation was performed with the UHS-20 stimulation device (Biotronik, Lörrach, Germany). The impulse width was 2.0 ms. The atrial and ventricular stimulation thresholds were determined at the beginning of the procedure to be 0.5 to 1.5 V. The stimulation amplitude was adjusted to twice the diastolic threshold. Programmed stimulation was performed in all patients, according to the following protocol:

- Determination of the sinus node recovery time at rates of 120 to 200/min.
- Determination of the effective refractory period of the right atrium and the anterograde conduction of the AV node by a single atrial extrastimulus, with 10-ms decremental shortening of the coupling interval after seven basic cycles during sinus rhythm and during stimulation with a heart rate of 100, 120, 150 and 180 beats/min, if needed.
- Incremental atrial stimulation for the determination of the maximal rate with 1:1 AV conduction.
- Incremental ventricular stimulation to detect the maximal rate with retrograde 1:1 AV conduction.
- Determination of the effective refractory period of the right ventricle and the conduction in ventriculo-atrial direction with a single extrastimulus during a basic cycle length of 500 ms from the apex of the right ventricle.

If there was no tachycardia inducible by a single extrastimulus, atrial double stimuli were applied during a basic cycle length of 330 to 600 ms. If no tachycardia was inducible by these stimulation maneuvers, the entire stimulation protocol was repeated after intravenous administration of Orciprenaline. The dose was adjusted to a heart rate of 50% above the initial sinus rate of the patient. For this purpose, 0.25 to 1.0 mg of Orciprenaline was needed.

After the induction of supraventricular tachycardias, the diagnosis of tachycardia was based on generally accepted criteria (4,9,10). The induced forms of AVNRT were defined as (1): typical AVNRT (the slow-fast form) and atypical AVNRT (the fast-slow form). The slow-slow form of AVNRT pertains to conduction of the impulse exclusively through two slowly conducting AV nodal pathways during tachycardia.

Dual AV node conduction properties were accepted as present if the A2-H2 interval (AH) increased by ≥50 ms during atrial extrastimulation, with 10-ms shortening of the coupling interval of the extrastimulus.

Ablation. We applied RF energy at the site of the slowly conducting AV nodal pathway. A 4-mm-long tip of a 4-pole, deflectable, 7F ablation catheter (Cordis-Webster, Watertown, Massachusetts) was placed through a long, bent, 8F sheath (DAIG Corp., Minnetonka, Minnesota) at the base of the triangle of Koch, according to anatomic and electrophysiologic criteria, so that the relation of the atrial to ventricular signal was 0.1 to 0.5, and a signal typical of a slowly conducting pathway was detected (i.e., a late atrial signal with high frequencies) (4,11).

For ablation, the RF generator EP-Shuttle (Stockert, Cordis-Webster) was used. The energy was applied in a temperature-guided mode, with a preselected temperature of 70°C and a maximal energy of 30 W and a maximal duration of 60 s.

The occurrence of junctional rhythms was assumed to indicate a successful energy application (2,12). Energy application was interrupted immediately if AV dissociation occurred during accelerated junctional rhythm (13), if the PR interval was prolonged, if an AV or ventriculo-atrial block occurred or if there was a sudden rise in impedance (14). After RF energy applications with accelerated AV junctional rhythms, additional energy pulses ("safety pulses") were applied, with a duration of 60 s. The end point of ablation was noninducibility of AVNRT.

Control stimulation. Stimulation was applied in a mode that was detected to induce the tachycardia before the first energy application. The detection of an AH jump or the occurrence of a single AV node echo beat was not considered as failure of ablation (15,16). However, if two consecutive AV node echo beats were recorded during stimulation, additional energy applications were performed.

If no tachycardia was induced, the whole stimulation protocol was repeated after a waiting period of 30 min.

In all patients in whom no AVNRT was inducible after ablation, Orciprenaline was administered in a dose given for tachycardia induction before ablation. During the Orciprenaline effect, the whole stimulation protocol was repeated again. An AV nodal pathway was considered to be

Table 1. Forms of Induced AVNRT

	n
Inducible AVNRTs	126
Only typical AVNRT	114
Only atypical AVNRT	5
Only slow-slow form of AVNRT	1
Typical AVNRT + atypical AVNRT	2
Typical AVNRT + slow-slow form of AVNRT	3
Atypical AVNRT + slow-slow form of AVNRT	1

AVNRT = atrioventricular node re-entrant tachycardia

modulated if tachycardia was not inducible after the energy application, and conduction over this AV nodal pathway was detected by an AH jump or the occurrence of AV node echo beats. An AV nodal pathway was considered to be ablated if there was no conduction through this pathway (i.e., if no AH jump or AV node echo beat was detectable and the refractory period of the AV node was increased).

Procedure duration and radiation exposure. The whole procedure of the electrophysiologic stimulation and ablation, from the puncture of the veins until the removal of the sheaths, including the waiting period, had a mean duration of 218 ± 60 min (confidence interval [CI] 206 to 230, range 90 to 380). The mean radiation duration was 28.1 ± 14.1 min (CI 23.4 to 32.8, range 5.0 to 58.0); and the mean radiation exposure was 70 ± 55 Gy cm^2 (CI 57.5 to 82.0, range 10 to 299). A mean number of 7.9 ± 7.1 (median 6 [CI 6 to 7, range 1 to 44]) RF energy applications were necessary. Because there were very short energy pulses, the duration of all energy application was calculated (mean 268 ± 209 s [CI 229 to 306, range 11 to 1,251], or 4.5 ± 3.5 min [CI 3.8 to 5.1, range 0.2 to 20.9]).

Monitoring after ablation. In all patients, the ECG was monitored by telemetry up to the next morning. In all patients, a 12-lead ECG was obtained, and an echocardiogram was obtained on the same or following day.

Statistics. For descriptive statistics, the mean or median values, with 95% CIs, were calculated, as appropriate (17). Data collection and calculations were performed on a Windows PC with statistical software (MedCalc, version 6.00.012, Belgium; and Confidence Interval Analysis, version 1.2, by Martin Gardner, London).

RESULTS

Inducible tachycardias. In 126 (96.2%) of 131 patients (CI 91.3% to 98.8%), AVNRT was inducible, mostly the typical form (114 [90.5%] of 126 patients of the patients with inducible tachycardias [CI 84.0% to 95.0%]) (Table 1).

In five patients (3.8%; CI 1.3% to 8.7%), no tachycardia could be induced during the electrophysiologic evaluation, despite Orciprenaline administration.

Modulation or ablation of an AV nodal pathway by RF energy application. In 126 (96.2%) of 131 patients (CI 91.3% to 98.8%), AVNRT was inducible. In the five patients in whom no tachycardia was inducible, all of whom had documented regular supraventricular tachycardia on the ECG and an AH jump, RF energy was applied at the typical site at the basis of Koch's triangle, until junctional rhythms were recorded. These patients were considered as successfully ablated (18).

In 129 (98.5%) of all 131 patients (CI 94.6% to 99.8%), the ablation procedure was successful. In two patients (1.5%; CI 0.2% to 5.4%), successful ablation could not be achieved. In one of these patients, the procedure was stopped after the 40th RF energy pulse, and in another patient with three AV nodal pathways, the procedure was terminated after unintentional ablation of the fast-conducting AV nodal pathway after the 8th energy pulse, to avoid total AV block.

In three patients (2.3%; CI 0.5% to 6.6%), a complete AV block occurred during the ablation procedure, which required pacemaker implantation.

In 31 patients (23.7%; CI 16.7% to 31.9%), no conduction through a slowly conducting AV nodal pathway was detectable. Thus, the slowly conducting pathways were considered ablated. In 90 patients (68.7%; CI 60.0% to 76.5%), one of the slowly conducting pathways was modulated by the energy applications; conduction over these pathways was recorded. However, tachycardias were not inducible, not even after administration of Orciprenaline.

Inducibility of tachycardias before and after ablation.

INDUCIBILITY OF TACHYCARDIAS BEFORE ABLATION. As outlined in the Methods section, electrical stimulation was performed first without an additional adrenergic drug effect. In 100 (76.3%) of all 131 patients (CI 68.1% to 83.3%), tachycardias were inducible, whereas in 31 patients (23.7%; CI 16.7% to 31.9%), no tachycardia was inducible without additional measures (Fig. 1). In 26 (83.9%) of these 31 patients with primarily no inducible tachycardia (CI 66.3% to 94.5%), AVNRT could be initiated by stimulation after administration of Orciprenaline, and in the remaining 5 patients (16.1%; CI 5.5% to 33.7%), tachycardia induction was not possible during the effect of Orciprenaline. In these five patients, energy was applied at the presumed site of the slowly conducting pathway (see previous paragraph). In this subgroup, ablation was considered successful if, during energy application, accelerated junctional rhythms were recorded (18); this was the case in all five patients.

INDUCIBILITY OF TACHYCARDIAS AFTER ABLATION. There were 121 patients with inducible tachycardias before ablation who were considered successfully ablated after the last energy pulse. Thirty minutes after ablation in these patients, control stimulation was performed without the effect of Orciprenaline. In none of these patients could AVNRT be induced.

In all 95 patients with inducible tachycardias without Orciprenaline administration before ablation, in whom ablation was initially successful and there was no AV block, electrophysiologic stimulation was repeated after administration of Orciprenaline. Tachycardia was not inducible in any of these patients. In the 26 (19.8%) of 131 patients (CI

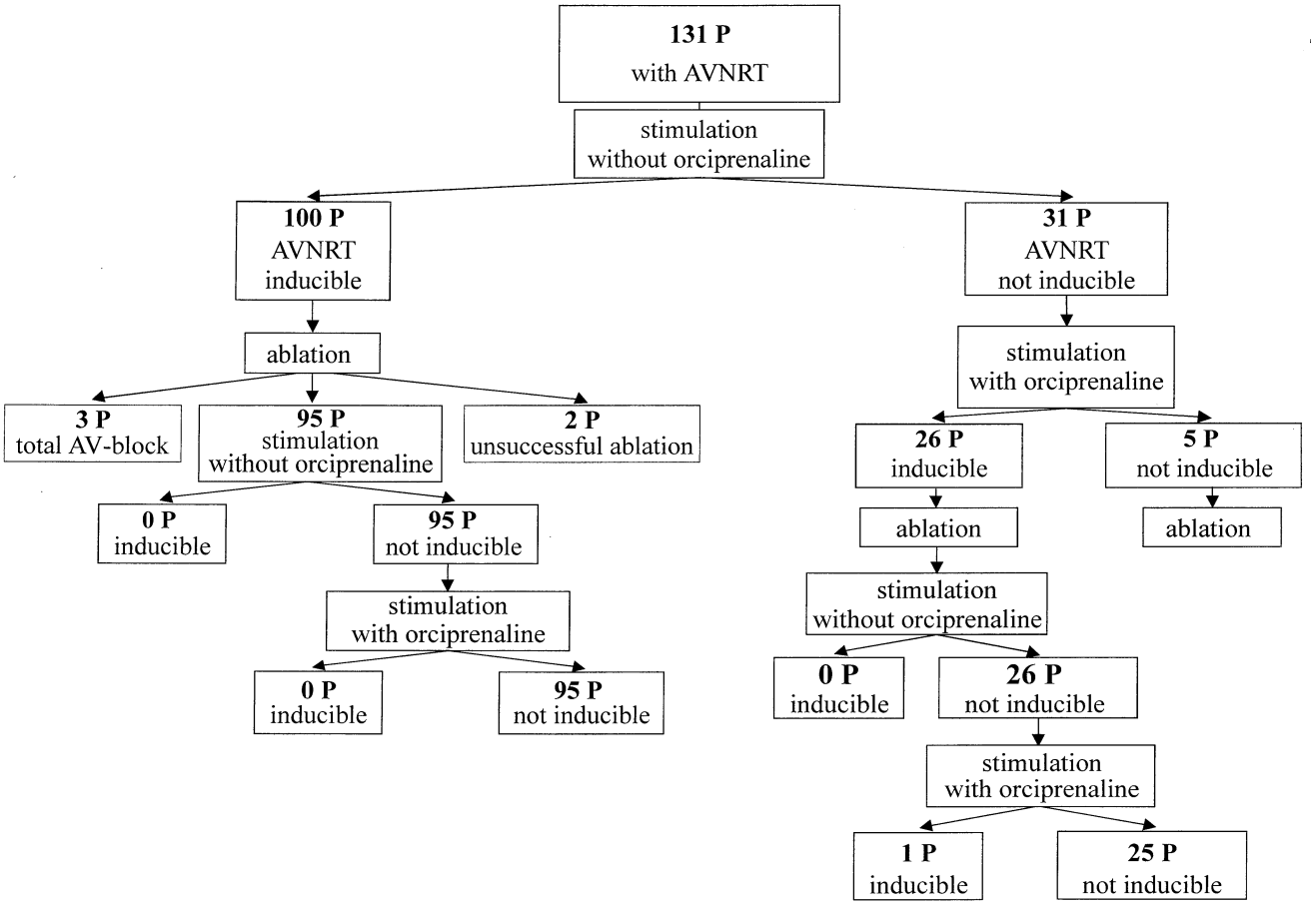

Figure 1. Diagram of the course of all patients with atrioventricular nodal re-entrant tachycardia (AVNRT) before and after ablation, without and during the effect of Orciprenaline. For more information, refer to text. P = patient.

13.4% to 27.7%) in whom tachycardia could be induced only during the Orciprenaline effect before ablation, an electrophysiologic evaluation was accomplished also with Orciprenaline. Tachycardias were inducible again only in a 62-year-old patient with typical AVNRT, in whom the slow AV nodal pathway was considered ablated initially (0.8%; CI 0.02% to 4.2%).

Complications. Three of 131 patients developed total AV block after ablation. In another patient, deep vein thrombosis occurred a few days after the ablation procedure. In this patient, a surgical intervention followed. An inherited thrombotic disorder was diagnosed later. This results in an overall complication rate of 3.1% (CI 0.8% to 7.6%).

Follow-up. A follow-up investigation was performed by telephone contact with the patients and their referring physicians. Two patients were lost to follow-up. The follow-up period of the other 129 patients was 998 ± 324 days (range 222 to 1,619). Three of these patients had a recurrence. In one patient with typical AVNRT, the tachycardia recurred spontaneously after completion of the ablation procedure, after uneventful stimulation before and with Orciprenaline. After six additional high-frequency pulses, the tachycardia was no longer inducible. No tachycardia recurred in the follow-up period of 1,131 days in this patient. In a second patient with typical AVNRT inducible without Orciprenaline before ablation, a recurrence was documented on the ECG two months later. The third patient with typical AVNRT and inducibility of AVNRT without Orciprenaline before ablation reported the same symptoms beginning four months after the ablation procedure. These paroxysms were not recorded by ECG. None of the five patients in whom tachycardia was not inducible before ablation, despite Orciprenaline administration, had a recurrence of tachycardia. This results in a recurrence rate of 2.3% (CI 0.5% to 6.7%).

DISCUSSION

Atrioventricular node re-entrant tachycardias represent (60%) the most common supraventricular tachycardias (1). Radiofrequency catheter ablation of those tachycardias is a routine procedure done by an interventional electrophysiologist. Success rates of ablation of these tachycardias are high (over 95%) (4,19). The question as to which criterion is chosen for control of success remains to be answered. Noninducibility of tachycardias after ablation under the effect of beta-adrenergic drugs is a widely accepted criterion. However, up until now, the extent to which this additional

control stimulation is reasonable has not been systematically investigated.

Importance of the effect of catecholamines. The portion of AVNRTs only inducible during administration of catecholamines is between 19.8% (our patient group) and 41.6% (9). The effect of catecholamines on both the fast-conducting and slow-conducting AV nodal pathway varies interindividually and cannot be predicted (9). Two mechanisms are possible for the inducibility of AVNRTs, which are only inducible during the effect of catecholamines. This was shown by Hatzinikolaou et al. (9) for isoprenaline.

- Catecholamines prolong the anterograde effective refractory period of the fast-conducting AV nodal pathway and increase the difference between the refractory period of the fast- and slow-conducting AV nodal pathway.
- When the difference of these refractory periods is reduced by the action of catecholamines, AVNRTs may be inducible if the conduction velocity of the slow-conducting AV nodal pathway is reduced by the effect of catecholamines and if the retrograde conduction is improved.

Because of these effects of the catecholamines, many investigators only consider AVNRT to be effectively ablated if the tachycardia is not inducible during the effect of catecholamines (2–7). Other working groups have conducted stimulation for control of the success of ablation without administration of catecholamines and do not consider control stimulation with catecholamines necessary (10,19,20).

Importance of stimulation with the effect of catecholamines before ablation. In the present group of patients, AVNRTs were inducible without additional provocation with beta-adrenergic drugs in 100 (76.3%) of all 131 patients (CI 68.1% to 83.3%). In a considerable proportion of patients (19.8%; CI 13.4% to 27.7%) (i.e., 26 of the 131 patients with AVNRTs), the tachycardias could only be induced during the effect of catecholamines. In the patient group of Hatzinikolaou et al. (9), this proportion was even greater, at 41.6%. The difference between their results and ours is explained by their less aggressive stimulation protocol, as compared with the one we used, because they did not use double extrastimuli in the atria.

Proportion of noninducibility of AVNRTs. In 5 (3.8%) of 131 patients in our study (CI 1.3% to 8.7%), no AVNRT was inducible, despite electrical stimulation after administration of Orciprenaline. Bogun et al. (18) have reported on 7 (2.1%) of 331 patients who had documented regular tachycardias with a narrow QRS complex, in whom no tachycardia was inducible, despite stimulation during the effect of catecholamines. In all of these patients, dual AV node conduction behavior was detected. The diagnosis of paroxysmal AVNRT is highly probable, but not proven. The only criterion for the success of ablation is the occurrence of accelerated, junctional rhythms during energy application. During follow-up, no patient in Bogun's group had a recurrence of tachycardia. Our patients were treated in the same way, and the diagnosis of AVNRT was assumed in these patients. The benefit of this strategy is confirmed in all of our five patients. The proportion of noninducible AVNRTs in our patient cohort is similar to that of Bogun's series (2.1%). Lin et al. (21) have reported a frequency of 5.2% in those patients.

Importance of control stimulation during the effect of catecholamines after ablation. In none of our patients in whom tachycardias were inducible without the effect of catecholamines was tachycardia inducible after ablation. In these patients, no tachycardia was inducible, even after administration of catecholamines. This means that control stimulation after ablation can be done in these patients without additional stimulation with catecholamines, because in none of these patients would a failure of ablation or an early recurrence of tachycardia inducibility be detected by this additional stimulation. This was demonstrated in the majority of all patients with AVNRT (95 [72.5%] of 131 patients; CI 64.0% to 79.9%).

In those patients in whom tachycardias are only inducible during the effect of catecholamines before ablation, a proarrhythmic effect of the energy applications has to be assumed to see inducible AVNRTs without the effect of catecholamines. Stimulation without catecholamines in these patients is not sufficient. In none of these patients was tachycardia inducible without catecholamines after ablation. The proportion of patients in whom tachycardia was inducible during the effect of catecholamines was small (1 [3.8%] of 26 patients [CI 0.1% to 19.6%]). If an investigator does not accept early recurrences or failures of ablation in ~4% of patients, he or she must perform control stimulation with catecholamines in this subgroup of patients.

Importance of a waiting period after ablation. Some investigators maintain a waiting period of 30 min after ablation to detect early recurrences or failures of ablation (2,10,20,22). Other investigators think that this is not necessary (3–7,19). In all of our 121 patients in whom AVNRTs were inducible and who were initially successfully ablated, a waiting period of 30 min was maintained. Induction of tachycardia after this waiting period was possible in only one patient and only after administration of catecholamines. This means that a recurrence of conduction of the AV nodal pathway occurs in a maximum of 1 (0.8%) of 121 patients (CI 0.02% to 4.5%). However, the tachycardia in this patient may have been induced immediately after the last energy application. The small number of patients detected after a waiting period of 30 min does not justify this waiting period.

Complications. Three of 131 patients had total AV block after ablation, resulting in a complication rate of total AV block of 2.3% (CI 0.5% to 6.6%), which is higher than the 1% rate expected for ablation of the slowly conducting AV nodal pathway. This may be due to our policy of applying

safety pulses, increasing the success rate and decreasing the number of recurrences.

Study limitations. An exact statement regarding the number of early recurrences after ablation after a waiting period of 30 min cannot be derived from our data, because immediately after ablation, no stimulation was performed according to the complete stimulation protocol. In only 0.8% of our patients was tachycardia inducible, again after a waiting period of 30 min. This means that a maximum of 0.8% (CI 0.02% to 4.5%) of patients with a recurrence of tachycardia inducibility can be observed after a waiting period of 30 min. To get an exact number of early recurrences with a waiting period of 30 min, the patients had to be stimulated immediately after the application of the last energy pulse and 30 min thereafter.

Conclusions. From the findings of the present study, we conclude that in patients with AVNRTs in whom tachycardia is inducible without catecholamines, stimulation with catecholamines after ablation is not necessary in addition to the usual control stimulation. An investigator should perform control stimulation in the subgroup of patients with inducible tachycardias after catecholamine administration only if he or she does not accept early recurrences or failures of ablation at a rate ~4%. A waiting period of 30 min after ablation before control stimulation is not mandatory, because a recurrence rate of tachycardia inducibility of only 0.8% is to be expected.

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