Transcatheter electrical AV junction ablation: predictors of success

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■ The initial and long-term results of transcatheter electrical ablation in 29 patients with drug-refractory supraventricular tachyarrhythmias were analyzed. Ablation was immediately successful (defined as induction of chronic complete heart block) in 25 patients (86.2%). Among the group in whom ablation was unsuccessful, there were more patients with ectopic atrial tachycardia and a higher incidence of narrow QRS escape rhythm following the initial ablation. A His amplitude equal to or greater than 0.3 mV was correlated with success. Complications of ablation included deep venous thrombosis and ventricular arrhythmias. Postablation stress testing was superior to ambulatory monitoring in identifying early return of atrioventricular conduction.

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SUPRAVENTRICULAR tachyarrhythmia (SVT) is a frequent reason for emergency room visits. Pharmacologic intervention is the appropriate first step, with treatment directed to suppression of precursors of tachycardia, alteration of tachycardia mechanism, and slowing of AV nodal conduction with subsequent control of ventricular response. It is often difficult to achieve these goals with drug therapy without causing significant systemic side effects, bradycardia, and frequent breakthrough of tachycardia. Permanent antitachycardia pacing techniques generally fail to control recurrence of SVT, frequently cannot adapt to variations in atrial tachycardia rate, ineffectively treat atrial fibrillation, do not influence AV nodal conduction characteristics, and commonly induce atrial fibrillation during the attempts to terminate reentrant SVT.[1] Because of these limitations, the preferable treatment for refractory patients is permanent interruption of atrioventricular nodal (AV) conduction in combination with a permanent pacemaker.

Ablation of AV nodal conduction destroys the sole exit pathway for supraventricular tachyarrythmias (except in those patients with antegrade accessory pathway conduction) regardless of their origin or mechanism.[2] Originally, this interruption was achieved through surgical techniques, with attendant hazards.[3,4]

A closed-chest transcatheter technique that delivers synchronized high-energy electric shock has proved effective.[5–12] Yet, the predictors of successful outcome are not yet well defined. In an attempt to resolve this question, we analyzed our initial and long-term data for the first 29 patients with drug-refractory, incapacitating SVT treated in our institution with

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transcatheter electrical AV junction or His ablation. Our objective was to identify clinical, electrocardiographic (ECG), and electrophysiologic predictors of successful outcome and to present a distinctive experience with pacemaker-related problems.

METHODS

Data were analyzed from all patients (n = 29) who underwent transcatheter electrical ablation of the AV junction from June 1984 through July 1988 at the Cleveland Clinic Foundation. Data were reviewed through November 1988 to include at least 3 months of follow-up. Our technique of transcatheter AV junctional ablation was reported previously.[10]

Most patients were given two shocks of 200 to 300 J, using the distal pole of a tripolar #6 or #7 French USCI catheter as the cathode; this also recorded the largest unipolar His bundle Potential. The anode of the cardioversion unit was attached to a patch electrode (R-2 Corp., Skokie, Ill.) positioned adjacent to the left scapula. The shocks were delivered after administration of IV methohexital sodium (Brevital).

All patients were observed initially in the laboratory for postablation arrhythmia or return of AV conduction; they also underwent hemodynamic monitoring. The response to 2 mg to 3 mg of IV atropine administered within 30 minutes of electrical ablation was assessed in five patients.

Following the procedure, patients were monitored by telemetry for several days before discharge. Permanent pacemakers were implanted within 48 hours of the procedure in 20 patients; the other 9 had previously implanted pacemakers for pre-existing symptomatic bradycardias). Postablation ECG assessment included single channel telemetry monitoring with continuous taping (all patients), predischarge exercise stress test (11 patients), and two-channel Holter monitoring at discharge (16 patients).

Successful ablation was defined as induction of persistent or chronic complete AV block during the entire follow-up period.

RESULTS

Patient population

The patient population consisted of 29 patients, including 17 (58.6%) women. The mean age was 58.3±12.7 years (range 30 to 80 years). Underlying organic heart disease was present in 20 (68.8%) patients, including primary myocardial disease in 8, coronary artery disease in 9, rheumatic mitral valve disease in 2, and essential hypertension in 1. Six of the patients had moderately severe chronic obstructive pulmonary disease complicating the management of their SVTs.

The most common type of SVT requiring ablation was atrial fibrillation, atrial flutter, or both (18 patients, 62.2%). Other types of SVT included ectopic atrial tachycardia in 6 patients (20.6%), AV nodal reentry tachycardia in 4 patients (13.8%), and reciprocating orthodromic tachycardia in one patient (3.4%). None of the patients with ectopic atrial tachycardia had associated cardiac or pulmonary abnormalities, including pulmonary hypertension or cor pulmonale.

All 29 patients were incapacitated by SVTs or by intolerable drug side effects before they were considered for transcatheter ablation. The most common symptom was shortness of breath (17 patients). Six patients had severe dizziness and 3 had syncope. The fastest heart rate during SVT ranged from 140 bpm to 275 bpm (mean, 178±34). All patients were recently unresponsive or intolerant to a mean of 4±1 antiarrhythmic drugs (alone or in combination), including digoxin in 22 (75.8%), beta blockers in 17 (58.6%), verapamil in 21 (72.4%), conventional class IA antiarrhythmic drugs (quinidine, procainamide, disopyramide) in 23 (79.3%), flecainide in 10 (34.4%), and amiodarone in 13 (44.8%).

Ablation results

Persistent complete AV block was achieved after the first ablation session in 20 patients (68.9%), designated as Group I. AV conduction resumed in 9 patients, designated as Group II.

Conduction resumed in 6 patients during the same hospitalization, from 1 hour to 3 days following ablation, and in 3 patients from 6 days to 2 weeks following ablation. The procedure was repeated in 7 symptomatic patients, with a successful outcome resulting in 5.

Thus, permanent complete AV block was achieved in 25 patients (86.2%); intermittent AV conduction developed in an additional 2 patients, but they were asymptomatic on digoxin alone throughout the follow-up period and therefore had a clinically successful outcome.

The presence of ectopic atrial tachycardia was significantly higher in group II (55.5% *v* 5%, $P = 0.005$). The percentage of patients with no discernible structural heart disease other than tachyarrhythmia was higher in Group II than in Group I (55% *v* 20%), but the difference was not statistically significant.

TABLE 1
COMPARISON OF PRE- AND POST-ABLATION PREDICTORS OF OUTCOME

	Group I* (n=20)	Group II† (n=9)	*P* value
Preablation predictors			
Organic heart disease	16/20 (80%)	4/9 (44.4%)	NS‡
Ectopic atrial tachycardia	1(5%)	5(55.5%)	0.005§
His amplitude (mV)	0.36 ± 0.14	0.28 ± 0.14	NS
Total energy (J)	510 ± 217	422 ± 130	NS
Postablation predictors			
Zero escape rate	5(25%)	3(33%)	NS
Narrow QRS escape rhythm	1(5%)	5(45%)	0.022§
Escape rate (bpm)	24 ± 17	36 ± 23	NS
Negative atropine test	3/5	2/5	NS
Exercise test			
Positive	0/8	3/3	0.006§
Negative	8/8	0/3	
Holter monitoring			
Positive	0/9	4/7	0.019§
Negative	9/9	3/7	

*Group I, achieved complete heart block.
†Group II, resumed AV conduction.
‡NS = nonsignificant.
§= statistically significant.

The mean total stored energy delivered during the first session was 482±196 J. There was no difference in the total stored energy between patients in Group I and Group II. Comparisons of total stored energy and other variables are summarized in *Table 1*.

Unipolar His electrogram amplitude, measured in 23 patients, was 0.34±0.14 mV (range 0.1 to 0.55), with no significant difference between Group I (mean 0.36) and Group II (mean 0.28, $P = 0.18$). His amplitude ≥0.3 mV correlated with successful outcome in 81.2% of patients (*Table 2*). However, 42.8% of patients with His amplitude less than 0.3 mV had a successful outcome.

The intrinsic ventricular escape rhythm immediately following the ablation was zero in eight patients; yet three of them had resumption of complete AV conduction within 24 hours. The average escape rate when present was 37±12 bpm. The difference in escape rate between Group I (mean 24±17 bpm) and group II (mean 36±23 bpm) was not significantly different. However, the incidence of a narrow QRS escape rhythm was significantly higher in group II (45%) than in Group I (5%; $P = 0.022$).

Although five patients had no increase in escape rate in response to IV atropine, two of the five resumed AV conduction within 24 hours of the first ablation procedure. The predischarge exercise stress test was positive (ie, enhanced intermittent AV conduction) in all three patients who had late resumption of AV conduction while Holter monitoring was negative in three of them (*Table 3*).

During a mean follow up of 14.6±15 months (range, 3 to 56), complete heart block persisted in 25 (86.2%) patients. Among the four patients with return of AV conduction, two were asymptomatic on digoxin and two remained symptomatic despite other antiarrhythmic drugs.

Complications

Complications following the ablation procedures were deep venous thrombosis in two patients and nonsustained or short runs of VT (150 bpm to 170 bpm) in three. One of the three, who also suffered sustained torsade de pointe ventricular tachycardia and was successfully resuscitated, had a long QT interval and was determined to have had a proarrhythmic response to quinidine.

Pacemaker-related problems

Pacemaker-related problems were encountered in five patients. In one, undersensing and oversensing developed and was managed with reprogramming. In the other four, whose pacemakers had been implanted prior to the ablation procedure, acute pacemaker failure resulted in cardiac arrest in one patient, syncope in two, and near-syncope in one.

In the patient in whom cardiac arrest occurred, the pacemaker abruptly failed to capture the ventricle immediately postablation, resulting in asystole. The patient was successfully resuscitated and, after 5 minutes, the pacemaker began to capture the ventricle and functioned well throughout the follow-up period.

Syncopal episodes developed in two patients during the first or second weeks of follow-up. Both had intermittent loss of capture and failure to sense; one patient also had intermittent 3-second pauses along with oversensing. Both patients underwent pacemaker generator replacement.

The fourth patient suffered from marked fatigue and dizziness because of intermittent loss of capture documented during the third month of follow-up. Noninvasive pacemaker evaluation revealed failure to respond to programming or magnet testing, and, ultimately, this pacemaker was also replaced.

Deaths

Three patients died during the 3 to 12 months following ablation. None of the deaths was related to the ablation procedure or rhythm disturbance, but all three

TABLE 2
PREDICTIVE VALUE OF PREABLATION HIS AMPLITUDE

	Complete heart block	Resumed AV conduction	Predictive value (%) for success
His amplitude (mV)			
≥ 0.3 mV	13	3	81.2
< 0.3 mV	3	4	42.8

TABLE 3
PREDICTIVE VALUE OF POSTABLATION TESTS

Postablation tests	Complete heart block	ResumedAV conduction	Predictive value %
Negative exercise stress test	8	0	100
Positive exercise stress test	0	3	100
Negative Holter monitoring	9	3	75*
Positive Holter monitoring	0	4	100

*Predictive value for success.

patients had severe underlying heart disease. Respiratory failure, or cerebrovascular stroke, and systemic sepsis were the primary causes of death.

DISCUSSION

After initial closed-chest electrical ablation studies of the His bundle in dogs,[13,14] AV junction ablation techniques were applied successfully to a selected patient population.[5–12] The technique of closed-chest ablation has largely supplanted the open chest technique of cryosurgical ablation of AV nodal conduction for the management of refractory supraventricular tachyarrhythmias. In a recent study,[3] both techniques were found to be equally effective in creating complete AV block (88% in the catheter ablation group *v* 86% in the cryosurgery group) and to be associated with similar long-term mortality, but closed chest catheter ablation was associated with significantly less morbidity (12% *v* 42%).

The reported long-term follow-up results of transcatheter ablation are mainly limited to the multicenter ablation registry[8,9] (mean follow-up, 12±11 months; range, 1 to 52), and the French multicenter experience reported recently by Levy and associates[12] (mean follow-up, 12±10 months; range, 1 to 51). These reports were limited by their design method, with uncontrolled data from different centers using different methods.

We here report the experience of a single center reviewing the benefits, potential risks, and the various predictors of outcome of the technique in a group of 29 consecutive patients followed for a mean of 14.6±15 months (range, 3 to 56). The success rate for the first ablation session was 68.9%, which is comparable to 58% in the ablation registry[8,9] and higher than British experience (50%) reported by Nathan and colleagues.[7] When the ablation was repeated in 7 patients, chronic complete AV block was achieved in an additional 5 patients, 2 of whom required a third ablation session. During follow-up ranging from 3 to 56 months, AV block persisted in 25 patients (86.2%). Two of the 4 patients with resumption of AV conduction were asymptomatic on digoxin only. Therefore, the clinical outcome was successful in 27 (93.1%) patients.

Although both the registry report and the French groups had a similar overall success rate (85% asymptomatic), they had a significantly lower percentage of persistent complete AV block (64% and 41% respectively, compared to 86.2% in our study group).[8,9,12] The difference cannot be explained by the type of arrhythmias, the number of shocks, the energy delivered per session, His amplitude, or the percentage of patients undergoing more than one session.[8,9,12]

Mechanism of ablation

The exact mechanism by which the multiple forms of energy released during electrical ablation can produce tissue damage at the target site is not yet completely understood. Certainly current and voltage have been shown independently to produce tissue damage.[15] Temperature as well as barotrauma has been proposed as physical factors that potentially cause tissue damage. Holt and Boyd have suggested that current density may be the most important factor in permanent disruption of myocardial tissue.[16]

The peak physical effects generated within the ablation tissue may depend not only upon the type of energy delivered, but also upon the particular physical properties of the tissue.[17] The electrical and physical properties of normal vs diseased cardiac tissue have not been characterized. In our series we found that among the nine patients who had resumption of AV conduction after the first ablation session, five had no discernible organic heart disease. In four of these five patients, permanent complete heart block developed on the second ablation attempt.

We hypothesize that current may dissipate different-

ly in normal myocardium than in abnormal myocardium, with less peak current density in normal myocardium. This assumption needs further study, but higher levels of stored energy may be needed in ablations for patients with ostensibly normal myocardium.

Predictors of successful outcome

His amplitude. The recording of sizeable bipolar or unipolar His potentials is a prerequisite for any AV junction ablation procedure. There has been considerable debate about the importance of preablation unipolar His amplitude. While some authors[8,11] demonstrated a significantly higher recorded His amplitude among patients who responded with chronic complete AV block, others[18] found successful ablation was not related to the size of the unipolar His electrogram. We found that a His potential ≥0.3 mV predicted a successful outcome, but 42.8% of patients with His amplitude <0.3 mV also had successful outcomes.

Total stored energy. The total stored energy delivered during initial ablation procedure did not predict ablation outcome. The effective current density and voltage at the target site seems to be the determining factor; Baraka and colleagues suggested more than 3 J/kg kilogram of body weight energy as a discriminant value for predicting success.[11]

QRS escape rhythm. Among the patients who resumed normal AV conduction after initial ablation, the incidence of narrow QRS escape rhythm was significantly higher (45% vs 5%, $P = 0.022$). This suggests that electrical induction of a significant lesion in the distal His bundle leading to a wide QRS (or infrahisian lesion) is more effective than ablation of the junction of the AV node and proximal His bundle. This finding has been supported histologically.[13] However, the absence of any escape rhythm in the first 30 minutes after ablation in eight patients did not correlate with procedure success with 3 (37.5%) patients in whom AV conduction resumed after ablation.

Atropine challenge. The results of IV atropine challenge during the first 30 minutes postablation did not predict long-term outcome of the procedure; AV conduction resumed in two of the five patients in whom no increase of heart rate occurred after IV atropine. This lack of effect of atropine is most compatible with an infrahisian escape, but still did not guarantee permanent AV block.

Exercise stress test. The predischarge exercise stress test predicted failure in all three patients who had late resumption of AV conduction, with intermittent increase in AV conduction. In two of these patients, Holter monitoring showed only a pacemaker-dependent rhythm. Exercise, possibly through a sympathetic stimulation mechanism, unmasked the presence of AV nodal conduction in those patients with later resumption of AV conduction.

Pacemaker-related problems. As the patient becomes pacemaker-dependent, postablation pacemaker-related problems may be considered indirect complications of the ablation procedure. The phenomenon of pacemaker system damage should be expected, as a similar type of damage has been reported with external direct current cardioversion in the presence of preexisting permanent pacemakers.[19] Also, it has been shown that intracavity shocks may raise the pacing threshold or make it impossible to pace either due to local or distant effects.[17] We recommend that pacemaker function after His ablation be monitored closely for any change in pulse generator or lead integrity. Replacement is recommended if the pulse generator circuitry is not functioning properly.

CONCLUSION

AV junctional electric transcatheter ablation is an effective procedure. Repeated ablation can enhance successful outcome, especially in those with normal myocardium, ectopic atrial tachycardia, or both. Although successful ablation was related to unipolar His amplitude equal to or more than 0.3 mV, a low amplitude His did not preclude successful outcome. Predischarge exercise stress testing was superior to ambulatory monitoring or atropine challenge for predicting postablation return of AV conduction. Permanent pacemakers implanted prior to the ablation procedure should be checked thoroughly and followed closely or be changed completely after the procedure.

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