TECHNIQUE

Long term results of fast pathway ablation in atrioventricular nodal reentry tachycardia using a modified technique

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Abstract

Objective—To assess immediate and long term success of “fast” pathway catheter ablation with graded use of radiofrequency energy in patients with classic atrioventricular nodal reentrant tachycardia (AVNRT) and evaluate clinical, procedure related, and electrophysiological features affecting long term results.

Design—31 consecutive patients with classic AVNRT at electrophysiological study, who were candidates for radiofrequency ablation. Patients were followed for an average of 24 months after ablation.

Setting—All studies and ablations were performed in an electrophysiological laboratory under fluoroscopic guidance using standard electrophysiological techniques.

Intervention—Radiofrequency application was performed at the site of proximal His bundle electrogram with A:V ratio of > 1. It was started at 10 W with increment of 5 W to a maximum of 25 W at 60 s. With the onset of junctional rhythm, atrial pacing was begun in order to monitor the PR interval. Application was terminated prematurely with a non-conducted P wave, continued prolongation of the PR interval beyond 50% of the baseline, or a threefold rise in impedance.

Results—Successful ablation was possible in 30/31 patients (97%) with an average of seven applications (range 1–10). It was associated with significant prolongation of PR interval ($P < 0.001$) and AV Wenckebach cycle length ($P = 0.01$). Ventriculo-atrial conduction was abolished in 24/30 patients (82%) with successful ablation. Two patients developed transient complete heart block (3 and 12 min) and one persistent right branch block. Four patients had late recurrence. Presence of ventriculo-atrial block was the only electrophysiological index predictive of long term success ($P = 0.01$).

Conclusions—Graded use of radiofrequency energy and atrial pacing to monitor PR interval decreases the risk of atrioventricular block in patients undergoing fast pathway ablation for AVNRT. Ventriculo-atrial block is predictive of

long term success and should be a preferred end point for fast pathway ablation.

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Keywords: atrioventricular nodal reentry tachycardia; fast pathway ablation

Atrioventricular nodal reentrant tachycardia (AVNRT) is the commonest cause of paroxysmal supraventricular tachycardia.¹ Radiofrequency (RF) catheter ablation is now the treatment of choice for management of these patients as it is associated with a success rate in the range of 90–95%.^{2–6} Successful ablation in these patients can be performed by ablation of either the “fast” or the “slow” limb of the reentrant circuit.⁴ The slow pathway is ablated at a relatively posterior septal site of the tricuspid valve annulus. It is guided either by slow pathway potentials, which are difficult to identify with confidence, or more frequently anatomically, in which case ablation is performed in the mid and posterior septal portion of the tricuspid valve annulus until tachycardia is not inducible. Slow pathway ablation is preferred over fast pathway ablation as it is associated with a lower risk of complete heart block.^{2–6} However, there is a wide area over which slow pathway potentials can be recorded. Fast pathway ablation is achieved in the region of the proximal His bundle with His:atrium electrogram ratio of 0.5 or less.^{3,4} It results in prolongation of the PR interval. Although relatively easy, as guided by a specific electrogram in a small anatomical area, fast pathway ablation has been reported to be associated with a higher incidence of inadvertent complete heart block. It has been suggested that graded use of RF energy decreases the incidence of heart block.⁴ In the present study factors affecting long term success of fast pathway ablation were assessed. RF energy applications were performed in a graded manner and with onset of junctional rhythm, atrial pacing was performed to monitor the PR interval.

Methods

PATIENT CHARACTERISTICS

Over the period of this study, fast pathway

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ablation was attempted in 31 consecutive patients with the classic variety of AVNRT.¹⁷ Mean age of the patients was 58 years (range 18–80). There were nine men and 22 women. Average duration of symptoms was seven years (<1–35 years). All patients had palpitations and seven also had syncope. Three patients had coronary artery disease without significant ischaemia. Standard electrophysiological techniques were used. During the study surface electrocardiographic leads I, 2, and V1, and high right atrial, proximal, and distal His bundle, and proximal and distal coronary sinus electrograms were monitored continuously. Atrial and ventricular stimulation protocols were used to identify the antegrade and retrograde atrioventricular conduction characteristics. If sustained AVNRT could not be initiated at the baseline study despite two extrastimuli, the stimulation protocol was repeated with an isoprenaline infusion. Standard criteria were used to establish the diagnosis of dual atrioventricular nodal pathways and atrioventricular nodal reentry.⁷

ABLATIVE PROCEDURE

A 7F deflectable quadripolar catheter with a 4 mm bulbous tip electrode (Mansfield Scientific) introduced through the right femoral vein was used for ablation. The catheter was positioned to obtain a bipolar recording of the His bundle deflection. It was then withdrawn and rotated anteriorly until it recorded a ventricular deflection that was smaller than the atrial deflection, with atrial:ventricular electrogram ratio of >1 and His bundle potential of <100 μ V, and there was no beat to beat variation, the latter indicating a stable catheter tip position. If initial application of RF failed, the above procedure was repeated in an attempt to obtain better tissue contact. If a satisfactory electrogram could not be obtained from the anterior septal site of the tricuspid annulus, the ablation catheter was gradually rotated posteriorly to see if the target electrogram (A:V ratio of >1 with relatively small His bundle deflection) or the earliest atrial activation during tachycardia could be recorded from a relatively posterior septal site. At the target site RF application was started at 10 W and was increased by 5 W every 15 s to a maximum of 25 W. Atrial pacing at 100–110 beats/min was begun with the onset of junctional rhythm so as to consistently capture the atrium. The PR interval was closely monitored. RF energy application was terminated with continuing PR prolongation

beyond 50% (fig 1), occurrence of a single non-conducted P wave, two- to threefold rise in impedance, or at 60 s. Inducibility of tachycardia was evaluated after each RF application. Ablation was terminated when no tachycardia could be induced with atrial and ventricular premature stimulation with two extrastimuli before and during isoprenaline infusion. Ablation was repeated if two or more echo beats were inducible. If no tachycardia was induced, complete stimulation protocol was repeated to document the atrioventricular and ventriculo-atrial conduction characteristics. Postablative electrophysiological assessment was performed before isoprenaline infusion. Patients were followed one month after the ablation and were subsequently asked to report if they had recurrence of symptoms. Up to date telephone follow up was available in all patients.

STATISTICAL METHODS

Electrophysiological variables are expressed as mean (SD). Statistical comparisons of pre and post ablation electrophysiological variables were performed by Student's *t* test for paired and unpaired values. Clinical variables, and pre and post ablation electrophysiological indices in predicting long term success of fast pathway ablation were assessed in the Cox stepwise regression analysis. Association of ventriculo-atrial conduction and late recurrence of AVNRT was evaluated in addition by Fisher's exact test. A probability value of <0.05 was considered statistically significant.

Results

IMMEDIATE RESULTS

All 31 patients had evidence of dual atrioventricular nodal pathway physiology. AVNRT was induced by premature atrial stimulation (25 patients) or rapid ventricular pacing (two patients), and required isoprenaline infusion in the other four. Using the above technique, "fast" pathway ablation was successful in 30 of the 31 patients (96%). In 26 patients successful ablation of the fast pathway was possible at the anterior-superior septal site of the tricuspid annulus with the delivery of an average of seven applications of RF energy (range 1–11). In five patients in whom ablation at the anterior septal site failed, the mid-septal area was mapped. In four of these patients, the earliest atrial activation during tachycardia was recorded at a site between the His bundle location and os of the coronary sinus. RF application was performed at these sites; however, in only two of these four patients could His bundle potentials or potentials similar to the timing of His-bundle electrogram be recorded from the site (posterior) of successful ablation (fig 2). As seen with ablation at the anterior site, ablation at these posterior sites in all four patients was associated with prolongation of the PR interval, loss of ventriculo-atrial conduction, and abolition of AVNRT.

Following successful ablation there was significant prolongation of PR and atrium-

Figure 1 Rhythm strip (electrocardiographic lead II) recording during radiofrequency (RF) application showing prolongation of PR interval. RF application was started 10 s before the recording of the above strip. Atrial pacing (as identified by the pacing spike) was begun with the onset of junctional rhythm. There was progressive prolongation of PR interval during 15 s of RF application.

Figure 2 Intracardiac electrocardiograms recorded in sinus rhythm before delivery of a successful radiofrequency pulse. The top 3 traces represent surface electrocardiographic leads I, II, and V1. Intracardiac electrograms shown from top to bottom are at sites of ablation catheter (AC), distal and proximal His bundle electrograms (HB1, HB2), and distal and proximal coronary sinus electrograms (CS1, CS2). Ablation catheter recordings, in addition to the atrial and ventricular electrograms, show a relatively low frequency potential occurring slightly before the rapid His bundle deflection on HB2. This was recorded at a relatively posterior site of tricuspid annulus where delivery of radiofrequency energy resulted in "fast" pathway ablation.

His intervals and of atrioventricular Wenckebach cycle length and no significant change in atrioventricular nodal effective refractory period (table). Six patients (19%) had evidence of retrograde conduction despite non-inducibility of AVNRT and seven patients had single reentrant echo beats. Retrograde conduction was by the slow pathway in five and probably by the fast pathway in one (short ventriculo-atrial interval).

Two of the 30 patients who had successful ablation developed complete heart block during RF application. In one it occurred at 15 s of RF application and the other at 35 s. In both patients heart block developed with RF application at an anterior site and was transient. In the first patient it recovered at 3 min of termination of RF application whereas in the other patient atrioventricular conduction recovered after 12 min. Surprisingly in both these patients the PR interval returned to normal within the next half hour. Immediately after ablation neither patient had inducible arrhythmia but one had ventriculo-atrial conduction. The latter patient had late recurrence of AVNRT, seven months after ablation. Two other patients had right bundle branch block, probably related to catheter movement to a distal position during RF application. Right bundle branch block has persisted in one patient and has recovered in the other. Two patients, who had PR interval

Electrophysiological indices before and after ablation in 30 patients who underwent successful fast pathway ablation. Values are means (SD)

Index	Pre-ablation	Post-ablation	P
PR (ms)	137 (19)	208 (32)	<0.001
AH (ms)	69 (20)	164 (48)	<0.001
HV (ms)	42 (11)	46 (14)	NS
AVERP (ms)	277 (42)	287 (50)	NS
AVWCL (ms)	313 (46)	356 (62)	= 0.01
VA block	0	24 (82%)	

AH, low right atrium to His conduction time as recorded at the site of His bundle electrogram; AVERP, AV effective refractory period; AVWCL, AV Wenckebach cycle length; HV, His bundle to ventricular conduction time.

of more than 300 ms after ablation of fast pathway, complained of a heavy feeling in the throat for two and three weeks after ablation respectively. These symptoms were not associated with any physical finding or pericardial effusion and were thought to be related to transient haemodynamic consequences of prolonged PR interval. In both these patients symptoms subsided spontaneously without any change in the PR interval and at three months follow up both were totally asymptomatic.

LATE RESULTS

During a follow up period of 12 to 30 months (average 24), four patients (13%) had symptomatic recurrences two weeks to nine months after apparently successful ablation. There was no difference in postablation electrophysiological features in patients with and without late recurrences. The role of number of RF lesions, changes in PR and atrium-His intervals, prolongation of atrioventricular Wenckebach cycle length, atrioventricular nodal effective refractory period, and ventriculo-atrial block in predicting long term success was assessed in a multivariate analysis. Absence of ventriculo-atrial conduction was the only electrophysiological feature predictive of long term success ($P < 0.01$). Three of the six patients with preserved ventriculo-atrial conduction developed late recurrences as compared with one of the 26 patients with no ventriculo-atrial conduction ($P = 0.01$, Fisher's exact test). Three of these four patients have undergone a repeat electrophysiological study and successful ablation of the fast pathway with loss of ventriculo-atrial conduction. In all three patients the recurrent arrhythmia was also classic AVNRT.

Discussion

In patients with AVNRT, catheter ablation of the "slow" or "fast" AV nodal pathways has been reported to have a success rate in the range of 55–94%, higher success rates being seen with increasing operator experience.^{3,4} The present study confirms the high success rate for "fast" pathway ablation. The major immediate complication associated with fast pathway ablation is a high incidence of inadvertent atrioventricular block, reported to be in the range of 8–21%.^{2,4} This could be related to the learning curve of the operator, the aggressiveness with which a successful result was pursued, the onset of junctional

rhythm making monitoring of the atrioventricular interval difficult, variable location of the fast pathway, mode of delivery of energy, and total energy delivered at the site of ablation. In large proportion of patients in the present study, adequate results were obtained at a relatively low energy level. Graded RF application allows energy to be titrated to each patient. As the energy used is relatively small, lesions are smaller and localised to the fast pathway. The use of high energy is more likely to involve both the slow and the fast pathways and thus more likely to lead to heart block. Secondly, application of RF energy in the region of the atrioventricular node leads to junctional rhythm making it difficult to monitor the PR interval, thereby increasing the risk of atrioventricular block. Atrial pacing with onset of junctional rhythm, at a rate faster than the junctional rate, helps in monitoring the PR interval; thus with any early evidence of atrioventricular block, RF application can be promptly stopped. In four of the 30 patients with successful ablation (13%), "fast" pathway ablation was achieved at a relatively posterior location along the tricuspid valve ring. Location of the fast pathway was confirmed by earliest activation at these sites during AVNRT. Furthermore post ablation electrophysiological features were consistent with those reported with fast pathway ablation, that is, prolongation of the PR interval and loss or marked prolongation of ventriculo-atrial conduction. These sites are conventionally targeted for "slow" pathway ablation. Ablation at these sites could explain complete atrioventricular block seen in some patients during slow pathway ablation.⁴

Limited data are available about long term follow up patients with AVNRT undergoing RF ablation.^{3,4} In the present study late recurrence rate was 12%, which is similar to that reported in previous studies. Electrophysiological features seen after ablation were similar to those reported by Jazayeri *et al* with successful fast pathway ablation.³ Sixty seven percent of their patients lost ventriculo-atrial conduction following successful fast pathway ablation. However, loss of ventriculo-atrial conduction was not correlated with long term success. Our study shows that loss of ventriculo-atrial conduction is the only feature predictive of long term success. It is likely that in patients who had persistent ventriculo-atrial conduction and were non-inducible, non-inducibility was related to transient effects of vagal stimulation as a result of RF energy application. A recent study by Kocovic *et al* has shown that RF application in the region of atrioventricular node leads to features suggestive of autonomic denervation of the conduction system and associated changes in heart rate variability which recover in due course of time and could explain transient non-inducibility in patients with persistent ventriculo-atrial conduction.⁸ It can also be hypothesised that in these patients RF application resulted in reversible tissue damage and not actual coagulation necrosis, while loss of ventriculo-atrial

conduction was related to coagulation necrosis and thus long term "cure".

It is suggested that prolonged PR interval associated with fast pathway ablation is non-physiological and could result in symptoms akin to pacemaker syndrome. None of the patients in the present series or in the previous studies has reported long term symptoms related to prolonged PR interval. It might, however, be a concern in patients with impaired left ventricular function. Secondly, as a result of a prolonged PR interval there appears to be a theoretical possibility of late atrioventricular block. However, none of our patients (including the two patients who had transient atrioventricular block) has had electrocardiographic evidence of atrioventricular block at a mean follow up of 24 months.

With increasing experience, slow pathway ablation is becoming the treatment of choice for patients with classic AVNRT and is usually attempted first. Our findings in consecutive patients suggest that fast pathway ablation can be safely undertaken in all patients with classic AVNRT and is best suited for patients with unsuccessful slow pathway ablation. Modification of the technique so as to closely monitor the PR interval, and graded application of RF energy, is likely to reduce or abolish the incidence of inadvertent heart block. Although there is a theoretical possibility of increased incidence of heart block when fast pathway ablation is performed after a failed attempt at slow pathway ablation, this was not the experience in a previous crossover study by Langberg *et al*, when fast pathway ablation was undertaken in all patients with failed slow pathway ablation.⁴

CONCLUSIONS

Fast pathway ablation is feasible in the majority of patients with classical AVNRT and should be attempted following failed slow pathway ablation. Graded RF energy application and atrial pacing with the onset of junctional rhythm significantly decrease the risk of complete heart block. In some patients fast pathway seems to have a relative posterior septal location. The only electrophysiological feature predictive of absence of recurrence appears to be loss of ventriculo-atrial conduction at ablation. A prolonged PR interval as a result of successful fast pathway ablation does not seem to be associated with any long term complication or delayed occurrence of AV block.

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IMAGES IN CARDIOLOGY

Pericardial cyst

This chest x ray shows an incidental finding of a smooth round opacity in the left cardiophrenic angle. Pericardial (spring-water) cysts are a rare developmental anomaly most commonly found in the cardiophrenic angles, and more frequently on the right. Occasionally they are located superiorly in the mediastinum. They usually do not cause symptoms or signs and are invariably benign. Computed tomographic scanning is a useful method of distinguishing between cysts and solid tumours.

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