



Arrhythmia recurrences are rare when the site of radiofrequency ablation of the slow pathway is medial or anterior to the coronary sinus os

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Aims The site of successful ablation of the slow atrioventricular (AV) nodal pathway may be located in the posteroseptal or midseptal area. We have previously shown that the site of successful radiofrequency (RF) ablation of the slow pathway, rather than residual slow pathway conduction correlates with AV nodal re-entrant tachycardia (AVNRT) recurrences, with more recurrences noted in inferoposterior (to the coronary sinus os) locations. Accordingly, we have since modified our approach, and in a consecutive series of 105 patients we have performed slow pathway RF ablation exclusively at medial or anterior locations, with the objective of prospectively examining the recurrence rate of AVNRT incurred with this approach.

Methods and results The study included 40 men and 65 women, aged 42 ± 18 years, having RF ablation for symptomatic AVNRT exclusively in anterior to the coronary sinus os locations. A combined anatomical and electrophysiological approach to slow pathway ablation was employed. This series of patients was compared with the previous series of 55 patients (historical group) with AVNRT undergoing RF ablation at both inferoposterior and anteromedial locations.

The mean cycle length of the induced AVNRT was 329 ± 48 ms. RF ablation was successful in all patients (100%). A mean of 7 ± 6 lesions were applied. Persistent

jump or echo beats were noted in 48 patients (46%). The procedure lasted for 2.1 ± 1.0 h. Fluoroscopy time was 23 ± 14 min. Procedures were complicated by heart block in two patients (1.9%). Over 26 ± 19 months, there has been only one recurrence of AVNRT (1%). The historical group had similar age (37 ± 18 years), gender (17 men/38 women), AVNRT cycle length (340 ± 60 ms), number of RF lesions (9 ± 6), or residual slow pathway conduction (42%), but longer fluoroscopy time (41 ± 25 min) and procedure duration (4 ± 1 h), and a significantly higher recurrence rate (seven patients/13%) ($P=0.004$) at a much shorter follow-up period of 12 ± 8 months.

Conclusion AVNRT recurrences are rare (1%) when slow pathway RF ablation is performed in medial or anterior locations at the tricuspid annulus, rather than in inferoposterior sites, whereby a higher (13%) recurrence rate has been previously noted.

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Key Words: Radiofrequency ablation, cardiac arrhythmias, atrioventricular nodal re-entrant tachycardia, arrhythmia recurrences, slow pathway of the atrioventricular node.

Introduction

Radiofrequency (RF) catheter ablation of the slow pathway has been the preferred target to effect cure in a safer (compared with fast pathway ablation) and highly successful way in patients with atrioventricular nodal

re-entrant tachycardia (AVNRT)^[1–10]. The site of successful ablation of the slow pathway may be located in the posteroseptal or midseptal area. We have previously shown that the site of successful RF ablation of the slow pathway, rather than residual slow pathway conduction correlates with AVNRT recurrences, with more recurrences noted in inferoposterior (to the coronary sinus os) locations^[6]. Accordingly, we have subsequently modified our approach, and in a consecutive series of 105 patients we have performed slow pathway ablation exclusively in medial or anterior locations and have prospectively examined the recurrence rate incurred with this approach.

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Table 1 Clinical and procedural characteristics of 105 patients undergoing radiofrequency ablation of the slow pathway at sites anterior to the coronary sinus os

Men/women	40/65
Age (years)	42 ± 18
Symptoms	
Palpitations	61
Presyncope	35
Syncope	9
Cycle length of AVNRT (ms)	329 ± 48
Procedural success	100%
Accelerated junctional rhythm	99%
Residual slow pathway	48 (46%)
Complications	
Complete heart block	2 (1.9%)

AVNRT=atrioventricular nodal re-entrant tachycardia.

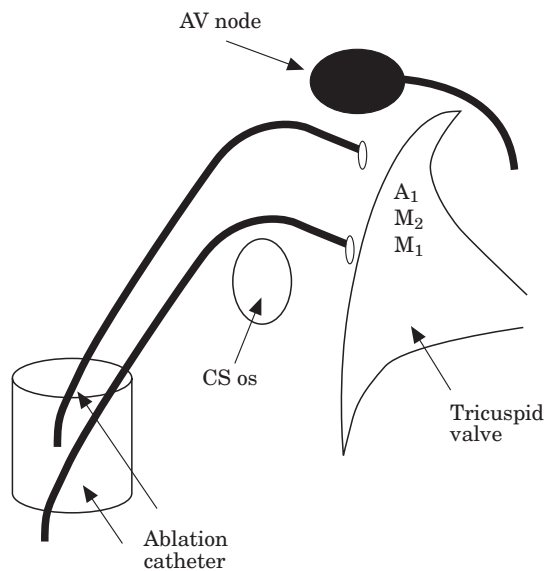


Figure 1 The scheme illustrates the proposed direct midseptal approach to slow pathway ablation by applying RF current to anteromedial (to coronary sinus os) locations (M1, M2 and A1), which in the current study led to an extremely low recurrence rate (1%), compared with higher recurrence rates previously reported when ablation was initiated at inferoposterior sites.

Patients and methods

Patients

The study included 105 consecutive patients undergoing RF catheter ablation for symptomatic AVNRT at our institutions over the last 5 years (Table 1). These were 40 male and 65 female patients, aged 9 to 75 years (mean 42 ± 18), who underwent RF ablation of the slow pathway exclusively in medial or anterior sites located cephalad to the coronary sinus os^[4-6] (Fig. 1). Three patients having what appeared to be altered anatomy with His bundle recordings at lower sites located very

close to the coronary sinus, were excluded from this series, since RF ablation was effected in an inferoposterior site. One additional patient was also excluded, since slow pathway ablation failed on the right side and was successful only when performed on the mitral annulus. Procedures were performed with use of local anaesthesia and light sedation. Electrophysiological testing and RF ablation were performed during the same session in all but three patients. All patients gave informed written consent for the procedures.

Patients presented with recurrent episodes of palpitations (n=61), palpitations and pre-syncope (n=35), and palpitations and syncope (n=9). The presenting arrhythmia was narrow-complex tachycardia (n=101), wide-complex tachycardia (n=3), and syncope with no documented arrhythmia (n=1).

The results of the present prospective study were compared with those of an historical group of 55 patients which has been previously characterized^[6] (Table 2). Briefly, these were 17 men and 38 women, aged 37 ± 18 years who underwent RF ablation of the slow pathway for symptomatic AVNRT in both inferoposterior (to the coronary sinus os) and anteromedial sites.

Electrophysiological study

The diagnostic electrophysiological study (EPS) preceding the ablation, was performed in the fasting state after all antiarrhythmic agents had been discontinued for at least five drug elimination half-lives. Routinely, three 5F or 6F quadripolar electrode catheters were introduced from the left femoral vein and with fluoroscopy guidance were positioned at the high right atrium, across the tricuspid valve for His bundle recording, and at the right ventricular apex. A 6F steerable quadripolar catheter was placed in the coronary sinus from the right femoral vein. Standard recording methods, programmed stimulation techniques, protocols and definitions were employed^[2-8]. The diagnosis of typical or atypical AVNRT was made with use of classic criteria^[5,11].

Ablation procedure

After completion of the electrophysiological study, a 7F steerable quadripolar deflectable-tip catheter with a 4 mm distal electrode and 2-5-2 mm interelectrode spacing (Cordis-Webster, Baldwin Park, CA, U.S.A.) was employed for mapping and subsequent ablation with delivery of radiofrequency current. A combined anatomical and electrophysiological approach to slow pathway ablation was employed (Figs 1 & 2). The ablation site was identified by use of bipolar electrograms displaying a small atrial and a large ventricular deflection during sinus rhythm. Slow pathway potentials were sought^[2] (Fig. 2A) but not verified with pacing techniques. Fluoroscopically, in the right anterior

Table 2 Comparative data between the study group and historical controls

	Study group (n=105)	Historical control group (n=55)	P value
Age (years)	42 ± 18	37 ± 18	ns
AVNRT cycle length (ms)	329 ± 48	340 ± 60	ns
RF lesions	7 ± 6	9 ± 6	0.047
Persistent jump and/or echo beats	46%	42%	ns
Fluoroscopy time (min)	23 ± 14	41 ± 25	0.001
Procedure duration (hours)	2.1 ± 1.0	4 ± 1	0.001
Complete heart block	1.9%	0%*	ns
Follow-up (months)	26 ± 19	12 ± 8	0.001
Arrhythmia recurrences	1 (1%)	7 (13%)	0.004

AVNRT=atrioventricular nodal re-entrant tachycardia; ns=non-significant; RF=radiofrequency.

*Except for transient block observed in one patient.

oblique projection, the potential locations for ablation, identified as posterior-P_{1/2}, medial-M_{1/2} and anterior-A_{1/2} locations^[4,5], were grouped into a schema of two general areas, with *anterior* sites (M_{1/2} and A_{1/2}) located cephalad to the coronary sinus os (and caudal to the catheter recording of a His bundle electrogram), and *inferoposterior* sites (P_{1/2}) located at or below the coronary sinus os^[6]. This fluoroscopic view was utilized to guide placement of the ablation catheter at the tricuspid annulus in anterior to the coronary sinus os positions (M1-A1)^[4-7] (Fig. 1). A single patient who had initial ablation attempts targeting an inferoposterior site (P₂), had tachycardia recurrence at 6 h and required a repeat session, during which ablation was performed in anterior sites, and he was thus qualified to be included in the present study.

A conventional electrosurgical unit (Osypka 200S or Osypka 300 or Medtronic-Atakr) was used to generate RF current at a frequency of 500 kHz. The RF current was delivered between the distal electrode and a cutaneous indifferent dispersive pad positioned on the posterior thorax or left thigh. Once the target site was identified, 20–50 Watts of RF energy was delivered via the ablation catheter. In 91 patients, RF ablation was guided by monitoring the temperature at the catheter tip, which was limited to maximum 70°C. If accelerated junctional rhythm (Fig. 2B) occurred within 5–10 s, the RF current application was continued for 30 s, otherwise it was stopped and mapping and ablation attempts continued. If impedance rose during ablation, RF application was interrupted, the catheter was removed and cleaned prior to reinsertion. After each RF current application, programmed stimulation was performed to assess for the presence of slow pathway conduction and inducibility of AVNRT. The endpoint of ablation was to render AVNRT non-inducible with and without isoprenaline infusion in all but two patients. In two patients with clinically documented supraventricular tachycardia and evidence of slow pathway conduction, but with inability to induce sustained AVNRT, elimination of all slow pathway conduction was successfully targeted^[12,13].

Half-an-hour to 1 h after ablation, programmed stimulation was repeated with and without the infusion of isoprenaline. After the procedure, patients were monitored for 24–48 h prior to discharge. During this period serial electrocardiograms were obtained to evaluate for recurring arrhythmia, and an echocardiogram was performed to search for cardiac complications.

Patient follow-up and statistical analysis

After discharge from the hospital, patients were followed-up at our arrhythmia clinic or by their referring cardiologists every 3–6 months for the first year and annually thereafter. All patients after the RF ablation procedure received one aspirin (100 mg or 325 mg) tablet daily for 1 month; no patient was receiving antiarrhythmic drugs during follow-up. All values are expressed as mean ± SD. Comparative data were analyzed with use of the *t*-test for quantitative data or the chi-square statistic for qualitative differences. A *P* value <0.05 was considered significant.

Results

Procedural characteristics and ablation results

Electrophysiological study and RF ablation were performed during the same session in all but three patients. The mean cycle length of the induced AVNRT in 103 patients was 329 ± 48 ms (range, 220 to 450 ms). In two patients, AVNRT could only be induced with isoprenaline infusion. One patient had almost incessant tachycardia. Two patients with documented clinical supraventricular tachycardia and demonstrated dual pathway physiology of the atrioventricular node during the electrophysiological study, had no AVNRT induced despite the administration of isoprenaline and atropine.

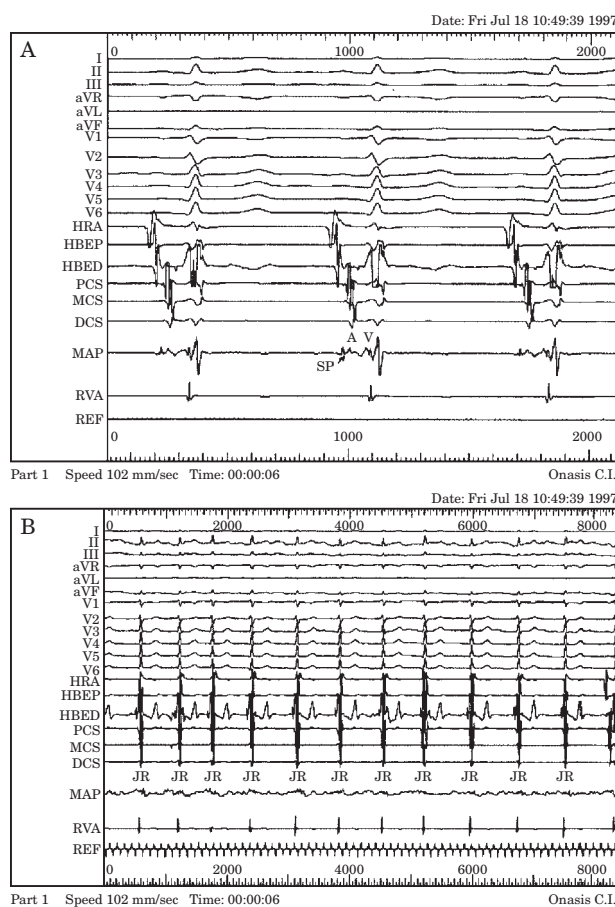


Figure 2 In addition to the anatomical approach, the mapping/ablation catheter identified the successful ablation site by recording bipolar electrograms displaying a small atrial (A) and a large ventricular (V) deflection during sinus rhythm, with no trace of a His bundle recording between the two electrograms. 'Promising' atrial signals comprised electrograms with sharp spikes preceding a broad-based recording (SP) (panel A). Almost always during successful RF current delivery, runs of an accelerated junctional rhythm (JR) were recorded (panel B). This rhythm was closely monitored to confirm stable rate and continuous 1:1 retrograde (ventriculoatrial) conduction. If rate acceleration or retrograde block were observed, RF current delivery was immediately discontinued. A 12-lead electrocardiogram and intracardiac recordings from the high right atrium (HRA), proximal (HBEP) and distal His bundle (HBED), proximal (PCS), mid (MCS) and distal coronary sinus (DCS), the right ventricular apex (RVA), the mapping/ablation catheter (MAP), and the reference electrode (REF) (monitoring RF current delivery) are displayed.

While the endpoint of ablation was non-inducible AVNRT in the 103 patients with reproducibly inducible AVNRT, in the two patients with non-inducible tachycardia, elimination of slow pathway conduction was successfully targeted. Radiofrequency ablation was initially successful in all patients (100%) with 1-26 RF applications (mean: 7 ± 6 , median: 5) (Table 1). Fluoroscopy time averaged 23 ± 14 min and total

procedure duration was 2.1 ± 1.0 h. One patient had, at baseline, first degree AV block which remained unaltered after slow pathway ablation. During AVNRT, AV conduction was 1:1 in all patients, except for one patient in whom both 1:1 and 2:1 AV conduction was observed.

Non-sustained junctional tachycardia was noted in all but one patient during the successful application of RF current (Fig. 2B). Residual slow pathway conduction with persistent dual AV nodal pathway physiology (jump in the A-H interval) and/or echo beats was still present after the ablation procedure in 48 (46%) patients.

Site of slow pathway ablation

Using a combined anatomic and electrophysiological approach, successful ablation of the slow pathway was effected with RF current applied at anterior sites ($M_1 - A_1$) of the slow pathway location (Fig. 1). In the single patient who initially had RF current applied at a posterior site (P2), AVNRT recurred at 6 h after the procedure necessitating a repeat session the next day, during which successful RF ablation was performed at an anterior site (M2) without any recurrence noted subsequently over 2 years. Interestingly, during RF ablation of the slow pathway in five of 105 (5%) patients, in addition to the typical (slow-fast) AV nodal re-entrant tachycardia, a slow-slow type of AV node re-entry was induced and finally successfully ablated upon completion of the ablation procedure with additional RF current applications in the area of the slow pathway.

Associated arrhythmias

Nine patients in this series had additional arrhythmias, which were successfully ablated during the same session. Among these there were: one patient with pre-excitation syndrome, two patients with a concealed accessory pathway, three patients with sinus nodal re-entrant tachycardia, one patient with right ventricular outflow tract tachycardia, one patient with right intra-atrial re-entrant tachycardia and one patient with both intra-atrial re-entrant tachycardia and atrial flutter. One additional patient had a bystander nodoventricular fibre which caused pre-excitation but did not participate in any arrhythmia, and, thus, it was not ablated.

Complications

Among all RF ablation procedures, complete atrio-ventricular block occurred in two patients (1.9%). In another patient transient complete heart block was observed which only lasted for 5 s. No other complications occurred in this series.

Follow-up

During long-term follow-up of 26 ± 19 months, there was one AV nodal tachycardia recurrence at 2 months, successfully treated with repeat RF ablation.

Comparison with the historical group

This series of patients was compared with the previous series of 55 patients with AVNRT undergoing RF ablation in both inferoposterior and anteromedial locations^[6]. This historical group had similar age (37 ± 18 years), gender (17 men/38 women), AVNRT cycle length (340 ± 60 ms), number of RF lesions (9 ± 6), or residual slow pathway conduction (42%), but longer fluoroscopy time (41 ± 25 min) and procedure duration (4 ± 1 h), and a significantly higher recurrence rate (seven patients/13%) ($P=0.004$) at a much shorter follow-up period of 12 ± 8 months (Table 2). More particularly, among 14 patients having successful ablation at an inferoposterior site the recurrence rate was 36%, compared with a 5% recurrence rate in 41 patients with anteromedial sites of successful ablation.

Discussion

Jazayeri, Akhtar and colleagues have provided an anatomical framework for slow pathway ablation at the tricuspid annulus by dividing the area into three sections (posterior- $P_{1/2}$, medial- $M_{1/2}$ and anterior- $A_{1/2}$) using the right anterior oblique fluoroscopic view^[4,5]. Subsequently, we proposed a schema of two general areas, with anterior sites located cephalad to the coronary sinus os (and caudal to the catheter recording a His bundle electrogram), and inferoposterior sites located at or below the coronary sinus os^[6]. With this anatomic designation we had shown that the site of successful RF ablation of the slow pathway, rather than residual slow pathway conduction, correlates with atrioventricular nodal re-entrant tachycardia (AVNRT) recurrences, with more recurrences noted when inferoposterior sites were selected as initial targets of slow pathway ablation compared with ablation performed at anterior locations. Thus, we then modified our approach accordingly, and in a consecutive series of 105 patients we have performed slow pathway ablation exclusively in anteromedial locations (Fig. 1). Initial success was high (100%) without incurring a particularly greater incidence of heart block (1.9%). The acute success of slow pathway ablation has been consistently excellent, whatever the initial site of ablation selected^[1-10]. However, it appears that initial ablation site selection becomes important when considering the rate of recurrences^[6]. Recurrences have been reported ranging between 5% and 10% when step-wise techniques starting in posterior sites have been

employed, regardless of the method of ablation guidance used, with temperature vs power monitoring, or electrophysiological vs anatomical approach^[1-10,14-17]. On the other hand, the results of the present study, in keeping with those of our previous study^[6], indicate that when an anterior site is selected for initiating ablation attempts, first it is associated with a high success rate without incurring a greater incidence of heart block, but most importantly it incurs a very low incidence of tachycardia recurrences (1%).

An atypical form of AVNRT (fast-slow type) has been reported to emerge in 3% to 12% of cases after successful ablation of typical AVNRT^[11]. We observed five cases (5%) of atypical AVNRT in this series, and the retrograde slow pathway involved in these tachycardias could also be effectively targeted and ablated in the anterior to the coronary sinus ostium sites with additional RF current applications. No tachycardia recurrences were noted in any of these five patients during follow-up.

In an attempt to minimize the risk of heart block, slow pathway ablation has traditionally been started in the posteroseptal area and when unsuccessful, RF energy is delivered in the midseptal area^[2-7]. However, the majority of successful slow pathway ablation has been effected in sites anterior to the coronary sinus ostium^[2,3]. Although anterior sites were not selected as initial sites of ablation in our previous study, it became clear that when ablation was successful in these anterior sites, the rate of tachycardia recurrences was lower (5%) when compared with the cases where successful ablation was accomplished at inferoposterior sites (36%)^[6]. By selecting the anterior sites as initial targets of slow pathway ablation in the present study, we confirmed that the recurrence rate of AVNRT remained extremely low at 1%. With regards to the safety profile of this approach, it is encouraging that the incidence of heart block was not significantly affected, even despite the fact of multiple ablation targets involved in 9% of patients in this series who had other associated arrhythmias; it remained below 2%, not significantly different from a heart block rate of 1.3% to 3% reported in previous studies^[18-20].

In a recent study where the posteroseptal and midseptal approaches for slow pathway ablation were randomized, there was no difference in the efficacy and safety of these two approaches, and thus one approach was not favoured over the other^[9]. However, in keeping with other investigators' suggestions^[8], our results give compelling support for a direct midseptal approach as the preferred technique to reduce significantly the incidence of AVNRT recurrences. Nonetheless, a caveat for such an endorsement of the anterior or midseptal approach to slow pathway ablation includes a word of caution when the ablation catheter is moved from a medial ($M_{1/2}$) to a more anterior site (A_1) (Fig. 1), where extreme care should be taken to avoid A_2 locations and thus risk of incurring injury to the compact AV node or fast pathway. Furthermore, one may encounter occasional anatomic variations, as those observed in three of our patients who were excluded from this series, where there

is an apparent inferior displacement of the AV node/His bundle with a His electrogram recorded very close to the coronary sinus os. In these cases an inferoposterior approach is indicated; or rarely failed right-sided attempts of ablation may point to a need for a left-sided approach to slow pathway ablation, which we observed in one of our patients, also excluded from this study.

Although there is obviously a very low incidence of AVNRT recurrences in the present study, plausibly attributable to the proposed approach with direct midseptal/anterior ablation of the slow pathway, the study is limited by the lack of randomization. However, the recurrence rate is much lower than that previously reported in the literature^[3,6,16,17], even in more recent reports^[14,19], and thus could not be ascribed solely to technological advances or increased experience, factors which, of course, can explain the decreased procedure and fluoroscopy time required in the current series compared with the historical group (Table 2). However, these variables would not be heavily implicated in the recurrence rate, since the acute success rate has been excellent under any circumstances (approximately 100%)^[1,2,6,8,10,16,19,20]. Nevertheless, one cannot completely exclude the possibility that the learning curve might have influenced not only the duration of the procedure but also the number of recurrences.

Finally, one may indeed consider that the major inconvenience of AVNRT ablation is a potential for complete AV block and not tachycardia recurrence, especially in a young patient. Therefore, special precautions and efforts should be undertaken to avoid AV block. Among these, we found useful the close monitoring of the junctional rhythm (Fig. 2B), with fast rates or occurrence of retrograde block indicating closer proximity to the compact AV node or to the fast pathway and thus dictating immediate interruption of RF current delivery. Essentially, however, this measure can be effectively applied only if a second experienced operator is also carefully monitoring the rhythm during the procedure, allowing the first operator to concentrate on watching the position of the ablation catheter under fluoroscopy to avoid accidental displacement and injury of the AV node. Other measures include avoidance of A2 locations, obtaining promising local electrograms (Fig. 2A), ensuring good catheter stability, achieving a temperature of at least 48–50°C and maintaining it for several seconds, and patient collaboration during the critical moments of RF current application by avoiding movement or deep respirations. Other investigators have proposed the use of newer localizing techniques (LocaLisa)^[21], or mapping guided by subthreshold stimulation^[22], all aiming at more effective and safe ablation procedures.

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