TRANSVENOUS RADIOFREQUENCY CATHETER ABLATION OF ATRIOVENTRICULAR ACCESSORY PATHWAYS

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ABSTRACT

Transvenous delivery of radiofrequency energy is an attractive new technique in nonsurgical treatment of cardiac arrhythmias. We used radiofrequency catheter ablation in two patients with tachycardias complicating the Wolff-Parkinson-White syndrome. The first patient was a 28-year-old male who had suffered cardiac arrest from rapid preexcited atrial fibrillation (shortest RR interval of 180 ms) due to a left anterolateral free wall accessory pathway. The accessory pathway was mapped by means of positioning a 7F quadripolar catheter with a 4 mm tip to obtain the shortest atrial to ventricular timing during preexcited sinus rhythm. Unmodulated radiofrequency energy (750 KHz) was applied unipolarly between the distal pole of the catheter against an indifferent plate at the back. Using an applied energy of 30W, this resulted in the disappearance of both anterograde and retrograde conduction. The second patient was a 26-year-old man with concealed left posterolateral pathway. This was ablated at the site which corresponded to the shortest ventriculatrial timing during sustained atrioventricular reciprocating tachycardia. There was no complication from this procedure and both patients were discharged on the fourth day after the procedure and returned to work soon afterwards. Radiofrequency ablation is a safe and effective means for the treatment of paroxysmal supraventricular tachycardias.

Keywords: Wolff-Parkinson-White syndrome, Accessory pathway, Catheter ablation, Radiofrequency ablation.

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INTRODUCTION

Patients with the Wolff-Parkinson-White (WPW) syndrome are susceptible to atrioventricular reciprocating tachycardias (AVRT) and/or preexcited atrial fibrillation (AF)[1,2]. For those who have life threatening arrhythmias, surgical resection of the accessory pathway has been considered a safe and effective treatment[3-6]. However, this entails the use of general anaesthesia and the use of cardiopulmonary bypass[3,4]. Catheter ablation using direct current had been tried, and some success had been obtained in the treatment of posteroseptal accessory pathways[7,8]. However, because of the barotrauma and the danger of cardiac damage, its use inside the coronary sinus for the ablation of left sided accessory pathway is necessarily limited. Radiofrequency energy is a new form of energy which produces dessication of cardiac tissue[9-10], and has been successfully used for atrioventricular (AV) nodal ablation in human beings[10]. We have successfully used this energy source in the cure of two patients with drug refractory arrhythmias complicating the WPW Syndrome.

PATIENTS

The clinical presentation and salient results of electrophysiology studies of the two patients are summarised in Table I. Both are young males suffering from drug refractory tachycardias associated with bypass tracts. Patient 1 who had overt WPW syndrome developed cardiac arrest following preexcited AF. Patient 2 had intermittent preexcitation (probably because of residual amiodarone therapy at the time of consultation). He had recurrent reentrant tachycardia, which although not rapid, was debilitating despite medical therapy.

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METHODS

Baseline electrophysiology study

Electrophysiology study was performed in the non-sedated state as previously described[11]. Antiarrhythmic agent was stopped at least 5 half-lives of the drug before the study. For patients previously on amiodarone, the latter was stopped at least 4 weeks prior to the procedure. Multipolar catheters were inserted via femoral and subclavian venous punctures. They were positioned at the high right atrium, AV junction, right ventricular apex and the coronary sinus under fluoroscopic guidance.

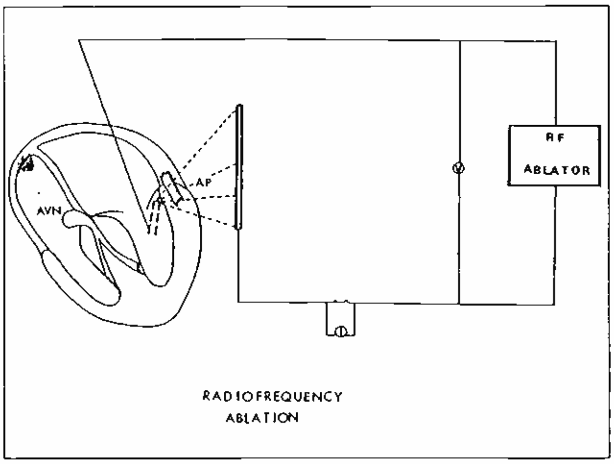
Conventional assessment of sinus node function, AV nodal conduction, atrial and ventricular effective refractory periods were performed. Accessory pathway conduction capacity was assessed by decremental pacing and using the extrastimulus technique. AVRT and AF were induced with either atrial and/or ventricular pacing. Accessory pathway location was mapped with unipolar recordings during sustained AVRT. Recordings were made using Mingograph 7 (Siemens Medical Inc. Sweden) using a frequency range of 0.05 to 500 Hz for unipolar recording.

Accessory Pathway ablation

Radiofrequency energy source

A custom modified electrocautery machine (Force 4, Valleylab, Boulder, Co, USA), capable of generating a 750 KHz unmodulated radiofrequency energy was used. The precise microbipolar configuration was modified such that the one pole was connected to the distal tip of the ablating electrode and the other to an adhesive patch placed at the back (Fig 1). The output power ranged from 1 to 60 W (in steps of 1). The actual energy delivered was measured using a voltmeter and current meter (across a 1.5 ohm resistor).

Fig 1 – Schematic representation of the layout of radiofrequency ablation. A unipolar endocardial to a large surface electrode configuration was used.



Radiofrequency Catheter

A 7F sterrable quadripolar catheter with a 4 mm distal tip was used (Wabster-Polaris, Mansfield Scientific Inc, Boxton, MA, USA). A 4mm tip was chosen because it was previously shown to be the most effective length for radiofrequency application[12]. The interelectrode distance was 0.5 cm.

Procedure and Mapping of accessory pathway

The radiofrequency catheter was passed retrogradely via the femoral artery into the left ventricle. The distal part of the catheter was deflected so that it could be positioned underneath the mitral valve. The disposition of the catheter (i.e. anterior, lateral and posterior) was guided by a coronary sinus electrode catheter using multiplane fluoroscopy. After insertion of the catheters, intravenous heparin 100 unit/kg was given as a loading dose, thereafter additional 1000 unit was given hourly during the procedure.

Detailed mapping was performed using electrophysiological method (Fig 2), either in sinus rhythm or during AVRT. In preexcited sinus rhythm, the shortest AV interval recorded within the AV groove represents the site of accessory pathway (Fig 2A). Similarly, the site which recorded the shortest VA timing during sustained AVRT was used to represent the site of retrograde insertion of the accessory pathway (Fig 2B). As

Fig 2A – Electrophysiological mapping of accessory pathway. Mapping is sinus rhythm. A catheter positioned at the site of the anterograde accessory pathway would yield a shorter AV interval compared with a remote (R) catheter position.

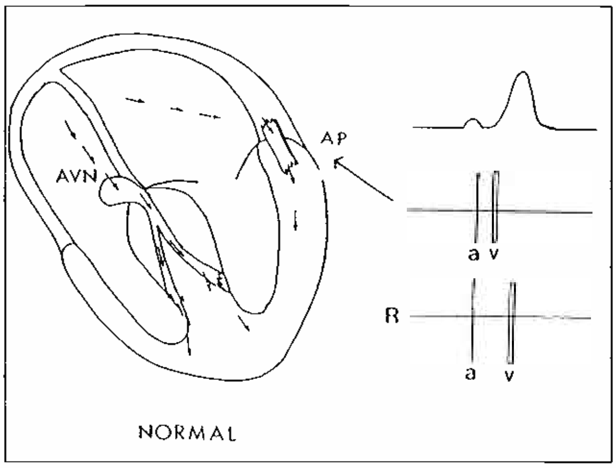
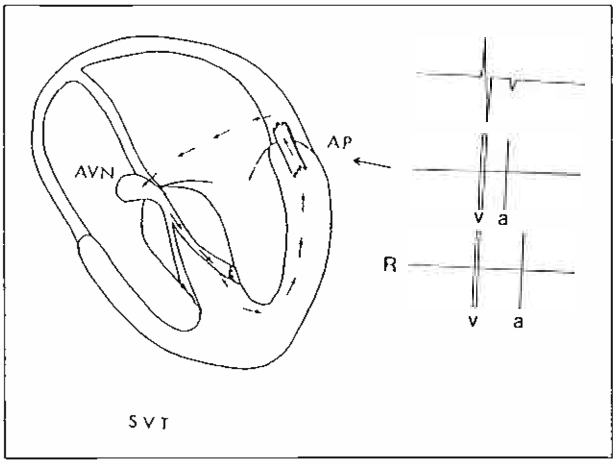


Fig 2B – Electrophysiological mapping of accessory pathway. Mapping during AVRT. 5 catheters positioned at the site of the retrograde inserted accessory pathway would yield the shortest VA interval compared with a remote (R) catheter position.



the ventricular insertion of accessory pathway on the left side is in general more discrete than the atrial insertion, both mapping and ablation were performed on the ventricular side of the accessory pathway.

Radiofrequency energy application was performed. As sites with short AV/VA timing (normally within 50 ms). A delivery evergy from 15 to 30W was used for up to 60 seconds. The end points were either disappearance of preexcitation, termination of AVRT or when impedance rose abruptly because of tissue charring and coagulum formation.

Post-radiofrequency electrophysiology study

A repeat electrophysiology study was performed at the same setting and 4 days and 3 months after radiofrequency ablation. Attempts were made to assess anterograde and retrograde conduction capacity and inducibility of arrhythmias.

RESULTS

Details of results of the electrophysiology studies of both patients are listed in Table I. Both remained symptomatic despite the use of amiodarone with and without an additional antiarrhythmic agent. A summary of the results of radiofrequency application is given below:

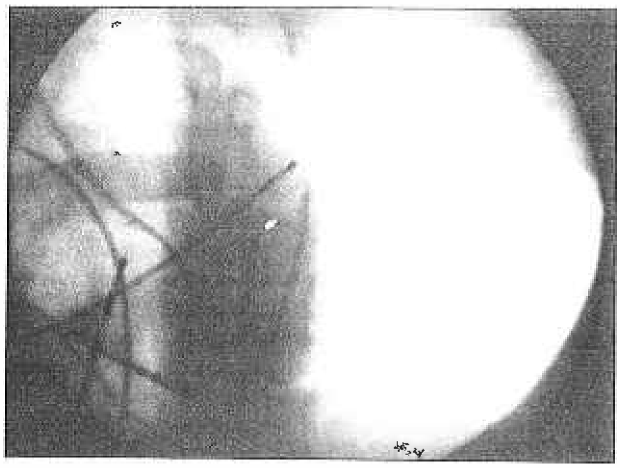
Patient 1

Mapping was performed in preexcited sinus rhythm, with a reference catheter in the coronary sinus. During manipulation of the catheter, frequent episodes of preexcited AF were induced, which required external DC version. 300mg of amiodarone was therefore given intravenously. The shortest AV, interval was localised at pole 1 (distal) of the coronary sinus catheter, which was located at the left lateral position (Fig 3A). Attempts at positioning the radiofrequency catheter and applications of radiofrequency energy at the AV groove around this region were initially unsuccessful. However, at the 8th application of radiofrequency energy at a site which corresponded to a recording of shortest possible AV interval of 40 ms (Fig 3B), complete disappearance of preexcitation resulted (Fig 4). The applied power was 30W for 45 seconds, although the actual power delivered was only 24W. Postoperative evaluation showed complete absence of anterograde accessory pathway conduction (1:1 AV conduction was through AV node and Wenckebach at 360 ms) (Fig 5) and absence of VA conduction (Fig 6). Although AF was still inducible, it was not preexcited and was well tolerated. There was no procedural-related complications and the patient was discharged on the 4th postoperative day, and he resumed his occupation within one week of hospital discharge and was entirely asymptomatic. An electrophysiology study performed at 3 months after the ablation showed normal anterograde AV conduction capacity of 350 ms. No retrograde conduction was documented.

Patient 2

Since there was no evidence of anterograde accessory pathway conduction during the procedure, mapping of the accessory pathway was performed during sustained AVRT. At the second application of radiofrequency energy at a site corresponding to a VA time of 80 ms (Fig 7), AVRT terminated at the fifth beat (Fig 8). An additional application was performed at the same site in sinus rhythm using the same energy output (25W energy for 60 seconds). There was retrograde conduction through the AV node after these applications and no complications from the procedure. Followup electrophysiology study at 3 months confirmed retrograde conduction through the AV node with conduction capacity of 320 ms.

Fig 3A – Localisation of accessory pathway in sinus rhythm in patient 1
Left anterior oblique cine view showing the disposition of the mapping catheter (arrowed).



DISCUSSION

Main Findings

The results of this study show that a non-surgical cure of patients with the WPW syndrome can be achieved using radiofrequency energy delivered via a percutaneous catheter technique. The presence of anterograde conduction allowed mapping during sinus rhythm, so that the ventricular insertion site of the accessory pathway can be ablated. The absence of preexcitation necessitated the mapping of the retrograde atrial

Fig 3B – Localisation of accessory pathway in Sinus rhythm in patient 1. The AV interval recorded in this position was shorter than the shortest AV interval in the coronary sinus electrode (CS) distal pole.

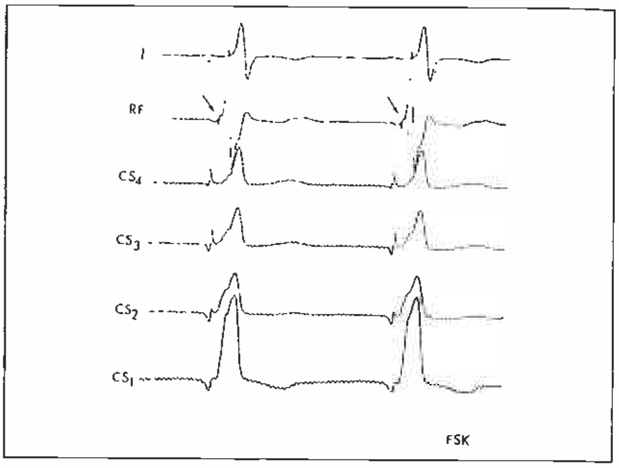


Fig 4 – Application of radiofrequency energy with a set power of 30W in the position recorded in Fig 3. At the ECG complex after this application, there is a sudden loss of preexcitation with simultaneous increase in the height of the T wave. Note the stable arterial pressure during the entire course of ablation.

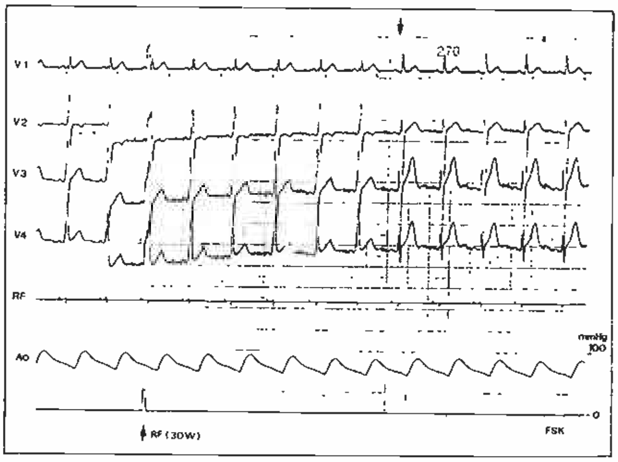


Table I – Clinical Profile of the Two Patients Undergoing Radiofrequency Ablation

Patient	Sex	Age	Presentation	E.C.G.	Tachycardias	Location of AP	Anterograde AP	Retrograde AP	Drugs
1	M	28	Palpitations Syncope for 10	Positive delta in II III V1-V5	AVRT (CL260ms) Preexcited AF (shortest PR 170ms)	Left Antero-lateral	< 180 ms	< 180 ms	Flecainide Amiodarone
2	M	28	Palpitations for 4 years	Negative delta in II III aVF (Intermittent) preexcitation)	AVRT (CL400ms)	Left Postero-lateral	—	270 ms	Sotalol Amiodarone

AF = Atrial fibrillation
AP = Accessory Pathway
AVRT = Atrioventricular reciprocating tachycardia
CL = Cycle length
M = Male

Fig 5 – Twelve-lead ECG's before and after radiofrequency ablation in patient 1. Note the disappearance of preexcitation and normalisation of the repolarisation phase.

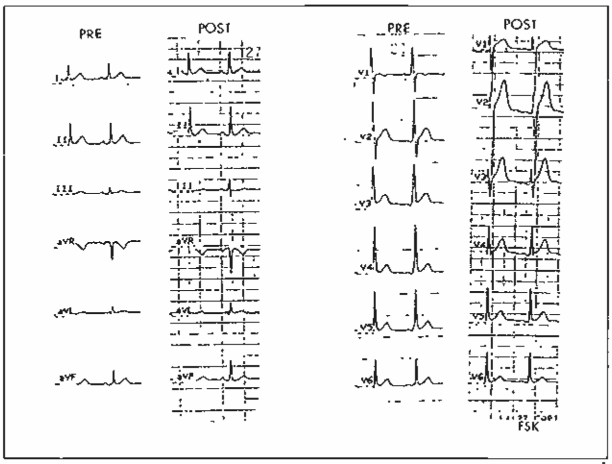


Fig 6 – Absence of VA conduction during constant rate ventricular pacing (cycle length 500ms) of patient 1 after radiofrequency ablation (CSd and CSp: distal and proximal bipolar coronary sinus recording; HRA: high right atrial recording; His: His bundle recording).

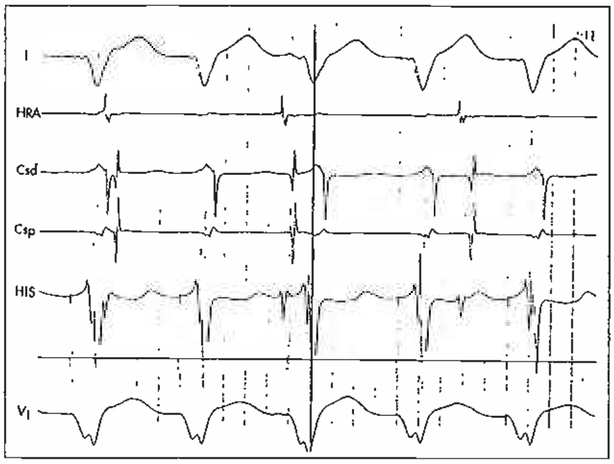


Fig 7 – Recording of VA timing during sustained AVRT in patient 2. The VA timing of successful ablation was 80 ms in this patient. (CS4-1 = unipolar recording from proximal to distal coronary sinus pole)

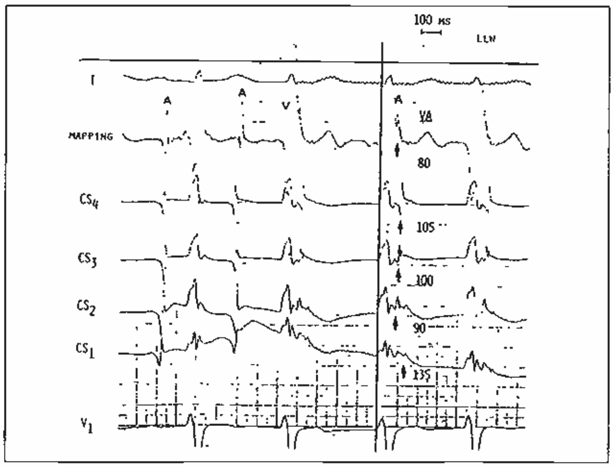
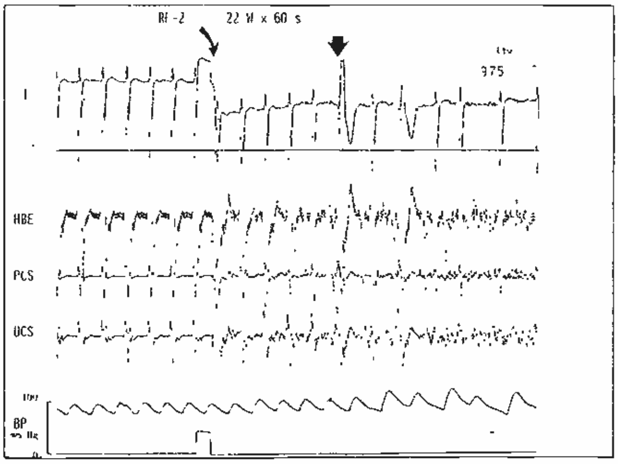


Fig 8 – Termination of sustained AVRT during application of radiofrequency ablation is position recorded in Fig 7. Heavy arrow shows a ventricular ectopic during radiofrequency application.



insertion site during sustained AVRT tachycardia. The procedures were well tolerated and with both patients resuming their previous occupation within one week of the procedure.

Direct current ablation

Direct current ablation is an effective method for the ablation of AV nodal conduction in patients with drug refractory atrial arrhythmias[13]. Although there was some success of direct current ablation of posteroseptal pathways[6,7], this form of energy has several disadvantages. As a large amount of energy is delivered within a short time interval, it creates very high voltages and currents, heat and arcing (fulguration) with associated barotrauma trauma[14]. Because of these effects and especially because of the high voltage generated, cardiac damage and myocardial depression can occur. Furthermore, at least in animal experiments, the lesions produced by direct current ablation are large but not circumscribed with inhomogeneous necrosis and haemorrhage[15]. These features may lead to the genesis of harmful ventricular arrhythmias. In addition, there is a potential risk of catheter damage during direct current ablation[16].

Radiofrequency energy

Radiofrequency energy is generated by an electrosurgical unit and is commercially available[17]. Its frequency ranges from 150 KHz to 1.0 MHz. Unmodulated radiofrequency energy is used for catheter ablation. This has the effect of causing slow cellular dissection and result in well demarcated homogeneous coagulation necrosis. The advantages of radiofrequency energy over direct current ablation are: (1) as muscle stimulation will not occur because of the highfrequency used, general anaesthesia will not be necessary; (2) the lesions are smaller and there is uniformed cellular destruction and hence less susceptibility to unwanted arrhythmias; (3) there is no gas bubble formation and (4) the integrity of the electrode catheter is usually preserved as interval arcing does not occur.

The size of lesions induced by radiofrequency depends on two primary factors: the electrode area and the tissue temperature achieved (Table II). For a given catheter bore diameter, an optimal electrode length was found to be 3-4mm[18], a longer electrode gives poor contact and connective heat loss. The final volume of the lesion so produced is proportional to the local tissue temperature, which in turn is dependent on a large number of variables (Table II)[19]. A temperature in excess of 100° will result in boiling and an increase in tissue impedance.

Table II
Determinants of lesion size during catheter delivery of radiofrequency energy

A.	**Electrode area**
	A 3-4 mm long catheter tip is associated with largest lesion.
B.	**Tissue temperature**
	Unipolar versus bipolar
	Contact pressure
	Convective heat loss
	Tissue impedance
	Current density

The monitoring of catheter tip temperature is the best means of allowing both safe and controlled delivery of radiofrequency energy.

Radiofrequency ablation of accessory pathways: current status

The first successful ablation of accessory pathway (right sided) in humans was described in 1987[20]. Since then a number of reports on successful radiofrequency ablation involving both right and left sided accessory pathways have appeared[21-29]. Several approaches have been used to ablate left sided accessory pathway. These include ablating via a patent foramen ovale or transeptal puncture to ablate the atrial side of the accessory pathway. Another method is the use of radiofrequency application within the coronary sinus against a back plate. Alternatively, an epiendocardial catheter approach using a catheter inside the coronary sinus and another catheter underneath the mitral annulus[22]. However, the same authors have found that a unipolar approach as described in this series to be superior[26,28]. Overall, the success rate for left sided accessory pathway ablation is over 90% with the use of a large tip electrode (100% success in Jackman's series[26] and 92% in Kuck's series[28]). Owing to the difficulty in stabilising the ablation catheter around the tricuspid annulus, the success rate of ablating right sided and posteroseptal pathways tends to be lower[21,28]. In all series reported so far, there is no mortality but one patient had acute occlusion of the circumflex artery which was treated promptly by angioplasty[27]. The average hospital stay was only 4 $\pm$ 2 days in one series[28]. On the other hand, the longest follow-up period of all those studies was only 15 $\pm$ 5 months, and long term results required further elucidation.

Future Development

A number of experimental studies have been reported in the literature concerning radiofrequency energy application.

To improve on the size of the lesion without producing excessive heating of the tissue, intermittent or pulsed radiofrequency ablation with an on-off cycle of 0.4 to 0.1 second had been tried[30]. This had the effect of 'cooling-up' of the catheter tip in between applications of radiofrequency energy and had resulted in larger lesion sizes compared with continuous radiofrequency energy delivery. Radiofrequency energy with two phase angles have been experimented, but could reduce the necessary energy to about half[31]. Another area of advancement is the development of new catheters, such as suction-catheter stabilisation of the electrode[32].

CONCLUSIONS

Closed chest ablation of accessory pathway will be popularised as a much less noninvasive curative treatment of the Wolff-Parkinson-White syndrome. The rapid technical advancement in this area is likely to extend the indications of this technique to wider groups of patients with supraventricular tachycardias. Indeed, as suggested by Morady et al[27], the diagnosis (by electrophysiology study) and immediate cure of paroxysmal supraventricular tachycardia (by transvenous catheter ablation using radiofrequency energy) is likely to be the trend for management of patients with supraventricular tachycardias.

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