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DERLEMELER

Radiofrequency Catheter Ablation of Supraventricular Tachyarrhythmias

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ÖZET

Kateter ablasyonunun hedefi bazı aritmilerden sorumlu reentry halkasını kalıcı olarak ve güvenle kesmektir. Bu uygulama supraventriküler aritmilerin tedavisinde 1982 yılından beri kullanılmaktadır. Özellikle radyofrekans enerjisinin ablasyonda kullanılmasından beri supraventriküler takikardilerin kateterle güvenli tedavisi yerleşik hale gelmiştir. Bu teknikle kontrolü, küçük çaplı lezyonların oluşturulması klinik uygulamada mükemmel güvenlik sınırları içerisinde çalışmaya olanak sağlamıştır. Günümüzde radyofrekans kateter ablasyon tekniği atriyoventriküler iletimi kesmekte, atriyoventriküler fonksiyonu modifiye etmekte, atriyoventriküler nodal reentrant takikardileri herhangi bir kalıcı pacemaker implantasyonuna gerek kalmadan ortadan kaldırmada başarı ile kullanılmaktadır. Ayrıca aksesuar yol ablasyonu da yüksek başarı oranları ile gerçekleştirilmektedir.

Sonuç olarak, supraventriküler takikardilerin radyofrekans kateter ablasyonu ile tedavisi ilaç tedavisine refrakter olan hastalarda ispatlanmış iyi bir tedavi seçeneğidir.

***Anahtar kelimeler:** Radyofrekans kateter ablasyonu, supraventriküler taşiaritmi*

Catheter ablation for the treatment of cardiac arrhythmias was introduced in 1982 and initially involved use of high energy direct current shocks [1-2]. This kind of shocks was associated with problems that limit its utility for ablation of the many areas of the heart. These are barotrauma resulting from a direct current energy discharge, larger lesions than desirable, damage of electrode catheters and pain [3].

With the advent of radiofrequency current, safe treatment of multiple arrhythmias has become commonplace [4]. The use of direct current shocks has been replaced with use of radiofrequency energy.

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The type of energy used in radiofrequency catheter ablation generally utilizes a continuous unmodulated sine wave with frequencies of 350 kHz to 1 mHz. The principal mechanism of radiofrequency induced injury to myocardium is presumed to be thermal. The frequency range that has been selected for radiofrequency catheter ablation is high enough so that rapid myocardial depolarization is avoided, but low enough so that electromagnetic heating is entirely resistive heating. It has been observed that myocardial injury and death reproducibly occurs once a temparature of approximately 50° C has been reached [5].

Radiofrequency current heats a narrow rim (<1mm) of tissue that is in direct contact with the electrode Deeper tissue planes are heated by conductive heat. The lesions resulting from the usual power deliveries are 5 mm in diameter [6] (Figure 1). During unipolar radiofrequency current delivery, the current will decrease in proportion to the square of the distance from the electrode [7]. Usually, radiofrequency current is routinely delivered via the tip electrode of an intravascular electrode catheter and other electrode (indifferent electrode) applied to the patient's skin.

The impedance of the whole system during ablation is 70-150 ohms. Increases in system impedance will increase the power required to ablate. Once the electrode tip tempature has risen to 100° C, tissue coagulates and the tip of the catheter becomes coated with charred debris referred to as coagulum [8]. To our knowledge, the most effective method of increasing radiofrequency lesion size has been by increasing the electrode size [9].

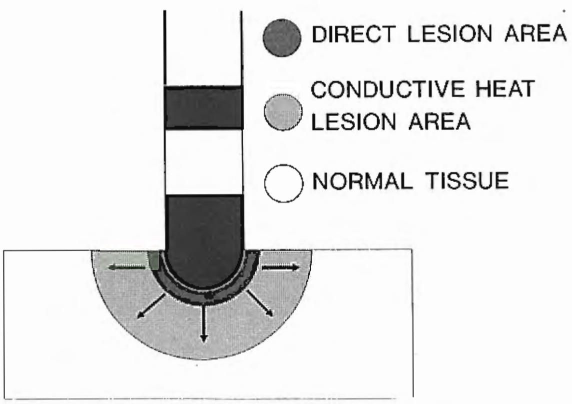

Figure 1. Schematic drawing of radiofrequency catheter ablation on the tissue. Radiofrequency current causes a narrow rim (< 1 mm) of tissue damage that is in direct contact with the electrode. The other lesion area, due to conductive heat, is 5 mm in diameter.

In the setting of clinical ablation we are using electrode catheters with 7 French diameter and 4 mm tip. In order to create optimal lesions for any condition, radiofrequency energy should be applied for at least 35 to 45 seconds with 60-70° C of tip catheter temperature [5].

In summary, radiofrequency energy produces small, discrete lesions with sharply defined homogeneous borders and does not cause barotrauma [10]. There is no need of general anaesthesia during the procedure. And there are much less acute and long-term complications when compared with direct-current shock. The most important complications during radiofrequency catheter ablation of supraventricular arrhythmias are cardiac perforation (low incidence), pulmonary embolism and local vascular complications. In our 278 patients radiofrequency ablation series we have not seen any cardiac perforation.

Atrioventricular junctional ablation

Ablation of atrioventricular (AV) junction may be necessary to control the ventricular response in patients with atrial fibrillation, atrial flutter and atrial tachycardia. This method has become an accepted method for arrhythmia control for patients defined above. This procedure should be reserved for patients in whom pharmacologic control of the ventricular response is difficult, or the drugs used produce undue side effects. After atrioventricular junctional ablation patients require implantation of a pacemaker. In our experience most patients were treated with VVIR pacemakers. So, a small percentage of patients may be exposed to the risk of AV asynchrony and to the risk of thromboembolism. But, appropriately selected patients benefit greatly from the procedure. Some reports show ablation of AV junction might be effective to prevent tachycardia-induced cardiomyopathy [11]. Improved quality of life, discontinuation of the use of antiarrhthmic drugs are other dramatic endpoints of successful AV junctional ablation.

The basic technique involves positioning an ablation catheter across the tricuspid valve to record a His bundle potential. Delivered energy should be directed at the joint where the largest His deflection is recorded using a typical bipolar filtered electrogram. The site of ablation that is usually targeted is the his bundle, and consequently, in 50 % of patients, the escape rhythm manifested a right bundle-branch block pattern. When right bundle branch pattern is associated with relatively narrow QRS, the escape rhythm is thought to arise in the fascicles.

If the energy is delivered proximally enough, the escape QRS complexes will be narrow and preceded by his bundle deflection [12]. Typically, when one is at a good site for ablation, accelerated junctional rhythms appear with the delivery of radiofrequency energy. However, this arrhythmia was also seen in approximately 25 % of the time when it was not accompained AV block. Once radiofrequency ablation has been attempted, the amplitude of the His bundle may markedly decrease [13].

In rare instance, total AV block cannot be obtained from the right side of the septum, however the conduction system can be approached from the left side of the septum using a retrograde transaortic technique, with placement of the ablating catheter just across the aortic valve in high septal region where a His bundle potential can be recorded [14]. Some authors prefer right-sided approach in older patients [15]. Souza et al suggested that radiofrequency ablation of the His bundle seems easier using a left-sided than a right-sided approach, reduces procedure and radiation time, avoids recovery of conduction [16].

Radiofrequency energy can successfully ablate the AV junction in approximately 95 % of patients [9,13,17]. In cases of failure, it is now well accepted that high energy DC shock should be attempted. A new report emphasizes the use of a bipolar application of radiofrequency energy between two electrodes located on the left and right side of the heart, respectively in patients refractory to radiofrequency energy delivered using unipolar mode [18].

A proarrhythmic effect of the radiofrequency ablation of the AV junction is unlikely. But a major concern in our studies involving radiofrequency energy ablation was an approximately 7 % risk (4 out of 56 patients) of ventricular fibrillation during the first few days after ablation [19].

Radiofrequency catheter ablation of atrioventricular nodal reentrant tachycardia

The mammarian atrioventricular node is a comlex structure, and the anatomic limits are not easily defined. The distal region of AV node is discretely organized and is contiguous with His bundle. The proximal portion of the AV node is a heterogeneous mixture of atrial myocytes and AV node cells. It is thought that AV nodal area bordered anteriorly by the septal leaflet of the tricuspid valve, posteriorly by the tendon of Todaro, and caudally by the coronary sinus ostium (Triangle of Koch) [20] (Figure (2).

Atrioventricular nodal reentrant tachycardia (AVNRT) is one of the most common cause of paroxsysmal supraventricular tachycardia. This arrhythmia is known to result from reentry in the region of the AV node, but precise site of the reentrant circuit has not been clearly defined. The reentrant substrate for AVNRT consists of at least two pathways (so called fast and slow), which have different electrophysiology characteristics. The fast pathways has a shorter conduction time and usually longer refractory period than the slow pathway. In common AVNRT, which comprises at least of 90 % of the cases, reentrant impulses engage the slow pathway anterogradely and fast pathway retrogradely. In the uncommon AVNRT, reentrant circuit utilizes a slow pathway retrogradely and a fast or another slow pathway anterogradely.

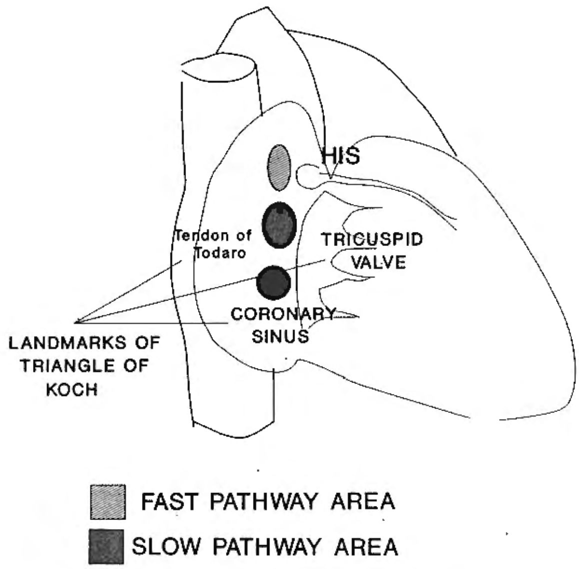

Figure 2. Schematic representation of the landmarks of the triangle of Koch. The Triangle of Koch is bounded anteriorly by the septal leaflet of the tricusplid valve, posteriorly by the tendon of Todaro, and cadually by the coronary sinus ostium. Selective fast pathway and slow pathway ablation sites are shown on the figure.

Dual AV junctional pathways may be the substrate of this arrhythmia and these are thought to fuse at their lower ends in the region of the His bundle. However, it is unknown what completes the circuit at the upper end of the AV junction. McGuire et al suggested that a common pathway of AV nodal tissue does not form a single exit to the atrium from the site of reentry [21].

Keim and colleagues' ice mapping data indicated that fibers that conduct at a faster rate are directed superiorly toward the tendon of Todaro and the foramen ovale, and slower conduction fibers are directed inferiorly along the tricuspid annulus toward the coronary sinus os. The data also showed that the retrograde insertion of fast fibers are more peripheral from the AV node and run along the tricuspid annulus. Slow fibers appeared to have a broader inser-i-on site, ranging from areas several milimeters posterior to the compact AV node to sites next to the coronary sinus os [22]. Thus retrograde activation of atrium via the fast pathway occurs anteriorly near the catheter recording the His bundle potential, whereas retrograde activation via the slow pathway occurs posteriorly near the coronary sinus ostium (Figure 2).

In the last few years, radiofrequency catheter techniques have been developed for selective ablation of either the fast or the slow atrioventricular nodal pathways. Our AVNRT ablation techniques are described below.

During the fast pathway ablation (anterior approach) the catheter is placed at the His bundle region to obtain a bipolar recording of His bundle deflection. This catheter is then withdrawn until it records an atrial (A) deflection that is at least as large as the ventricular (V) deflection (A/V>1) along with smallest (0.1 mV) or no His bundle potential. Energy delivery is at lower power levels and is raised in increments if the PR interval does not increase. If junctional extrasystoles occur, the energy delivery must be terminated, the goals of the procedure are **1-** prolongation of the PR interval, **2-** complete retrograde block over the fast pathway during ventricular pacing, **3-** noninducibility of the AVNRT.

During slow pathway ablation (posterior approach) the catheter is placed at the His bundle region to record either the most distal His bundle potential; then the deflectable tip is fully bent and the catheter is slowly withdrawn along the tricuspid septal annulus down to the most posterior aspect of the interatrial septum. This site is considered optimal if the bipolar recording obtained from the distal electrodes shows an A/V ratio, the catheter tip is unbent, and the catheter is moved upward in a stepwise approach towards the AV nodal area. The endpoint of slow pathway ablation is the inability to induce tachycardia. The PR interval and retrograde AV nodal conduction are unchanged.

Goy et al published the first report of fast pathway ablation using radiofrequency energy [23]. Calkins et al reported successful outcomes after fast pathway ablation in 44 patients with typical AVNRT. Eighty-four percent of patients had a successful outcome after one radiofrequency ablation session. Their final success rate was 95 % [24]. In the study by Jazeyri et al [25], fast pathway radiofrequency ablation has been performed with 95 % success rate and a 21 % complete AV block rate.

Slow pathway ablation has been performed with 91 % success rate and 0 % complete AV block rate [25]. In the series of Mitrani et al.[26] selective pathway ablation eliminated AVNRT without complete block

Table 1. Results of radiofrequency catheter ablation of atrioventricular nodal reentrant tachycardia

	Fast pathway (n=76)	Slow pathway (n=25)
Successful selective ablation	73 (96 %)	24 (96 %)
Complete atrioventricular block	3 (3.9 %)	1 (4 %)
Recurrences	9 (11.8 %)	3 (12 %)
Follow-up (months)	7.2 +/- 4	8.4 +/- 5

in 69 % of patients, and selective slow pathway ablation eliminated it without complete AV block in 90 % of patients.

Our radiofrequency ablation of AVNRT results are outlined in Table 1. We believe that fast and slow pathways can be selectively ablated to treat patients with AVNRT with a high success rate and a low and similar incidence of complete AV block and recurrences. And fast pathway ablation appears to be a faster procedure than slow pathway ablation [27].

Radiofrequency catheter ablation of accessory pathways

Preexcitations are induced by an accessory atrioventricular connection that traverses the atrioventricular insulation plane at some point outside the specialized axis. These connections are composed of "working" mycordium, but also may be composed of "specialized" myocardial cells. In right-sided connections, the bundle usually crosses the atrioventricular groove at the point at which the annulus fibrosis in deficient.

In left-sided connections, the bundle crosses more superficially (in the subepicardial fat) to the mitral annulus. Septal atrioventricular connections may cross the atrioventricular function from the coronary sinus to the membranous septum [27].

Functioning bypass tracts produce typical Wolff-Parkinson-White (WPW) ECG pattern of a short P-R interval (<0.12 sec), slurred upstoke of the QRS complex (delta wave), and a wide QRS complex (>0.12 sec).

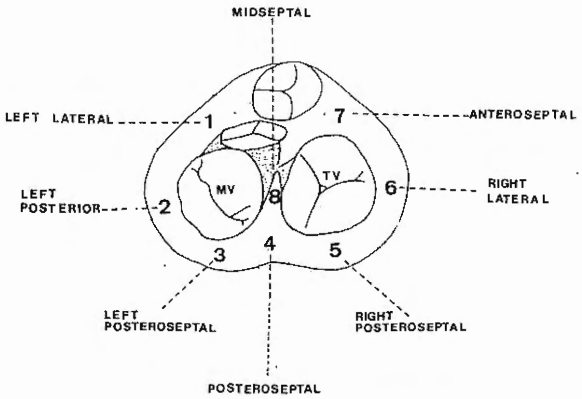

Figure 3. Schematic drawing of mitral and tricuspid annular area and location of accessory pathways. *MV: mitral valve, TV: tricuspid valve.*

The clinical significance of WPW syndromes is the high frequency of arrhythmias. Forty to eighty percent of patients with atrioventricular bypass tracts manifest tachyarrhythmias, the most common of which is a circus movement tachycardia (orthodromic supraventricular tachycardia) using the normal atrioventricular conduction system as the anterograde limb and the bypass tract as the retrograde limb of the reentrant circuit.

A reversed pattern of circus movement tachycardia (antidromic supraventricular tachycardia) occurs when anterograde conduction proceeds over the bypass tract and retrograde conduction proceeds over the normal atrioventricular pathway, or in many instances, an additional bypass tract. Atrial flutter-fibrillation may be the presenting arrhyhmia in patients with atrioventricular bypass tract. These episodes are potentially life threatening, because they can result in extremely rapid ventricular rates which precipitate ventricular tachycardia and/or fibrillation.

Precise anatomic identification of accessory pathway location is a prerequisite for successful ablation. We classified accessory pathways as left lateral, left posterior, left posteroseptal, posteroseptal, right posteroseptal, right lateral, anteroseptal and midseptal (Figure 3). Most frequently, they are found on the left ventricular free wall (left lateral) [23].

To localize left-sided accesory pathways, a catheter is advanced into the coronary sinus with the aim to determine the site of the earliest ventricular activation (shortest A-V interval) during sinus rhythm or atrial pacing and/or the site of earliest retrograde atrial activation (shortest V-A interval) during orthodromic tachycardia or ventricular pacing. During this procedure, the unfiltered unipolar coronary sinus catheter recordings contribute significantly to optimizing the accuracy of accessory pathway localization [29]. In single catheter technique, the mapping of the ventricular insertion of left-sided accessory pathway can be performed without the guidance of the coronary sinus catheter [30].

It was shown that the "weak link" of conduction along the accessory pathway is the ventricular insertion in the left-sided pathways. So, ablation attempt should be directed to this area, necessitating an arterial approach [31]. For this purpose, the catheter is advanced from the right femoral artery into left ventricle and positioned high against the mitral annulus, directly opposite to an electrode pair of the coronary sinus mapping catheter. Once the accessory pathway has been located, radiofrequency current delivered to the ventricular site. In cases where the ventricular approach fails to interrupt accessory pathway conduction, the next steps would be to advance the ablation catheter to the left atrium across the mitral valve, to find and ablate atrial insertion of accessory pathway or transseptal access into the left atrium for the same purpose.

Accessory pathways are seen less frequently on the right side. The weak point of right-sided accessory pathways appear to be atrial insertion site [31]. Therefore, ablation attempts should be performed from the atrial aspect of the tricuspid valve. In our laboratory, the tricuspid mapping catheter is introduced through the right femoral vein, and the catheter is positioned against the tricuspid annulus directly. The site of the earliest ventricular or retrograde atrial activation potential is recorded through the mapping/ablation catheter, which indicates the location of the accessory connection. As a major problem these pathways remain the most difficult ones to ablate. They can be multiple and have a higher rate of recurrence [32]. Another problem for this location is catheter instability which causes poor tissue contact with subsequent inadequate energy delivery to tissues.

Ablation of septal accessory pathways (anteroseptal, posteroseptal, midseptal) may harbour the risk of imparing atrioventricular conduction, since the anatomical vicinity of accessory pathway to the spesific conduction system.

Radiofrequency ablation of accessory pathways has revealed to be as effective with a better complication profile. Jackman et al showed that radifrequency ablation could be done with a 99 % success rate. During mean follow-up of 8 months, recurrence occurred in 9 % of patients. Mean procedure time was 8.3 hours during ablation. They had 1.8 % complication rate [33]. Calkins et al reporting their experience with 40 patients had a success rate of 93 %.

Their complication rate was 5 % and mean procedure time was 1.9 hour [24]. In the series of Kuck et al 275 patients underwent attempts at accessory pathway radiofrequency ablation. Success rate of radiofrequency ablation of left lateral accesssory pathways was 93 % with a 3-hour procedure time. The ablation attempts for the right free wall pathways were eventually successfull in 92 % of patients with mean 5-hour procedure time. Success rates of radiofrequency ablation of anteroseptal, midseptal and posteroseptal accessory pathways were 100 %, 100 % and 85 %, respectively. In this series, procedure related mortality rate was 0.3 % and nonfatal complication rate was 2.5 %. During a median follow-up period of 10.5 months, recurrences of accessory conduction after initially successful session were observed in 2.5 % of patients [34].

In our institute radiofrequency catheter ablation was used in 120 patients (mean age 35 years) until the end of January 1991. 53 % of patients had left free wall accesssory pathway, 5 % of patients had right free wall accessory pathway. Septal (anteroseptal, posteroseptal and midseptal) accessory were seen 42 % of patients. Five patients had multiple accessory pathways. Thirty-one patient had only concealed conduction.

In 115 patients (96 %) the ablation was successful. The procedure times were 90 minutes, 177 minutes, and 71 minutes in left lateral, right lateral and septal accessory pathway ablations, respectively. Complete atrioventricular block was observed in 3 patients (2.5 %). A septally located accesory pathway existed in all. An aortic perforation and a reversible blurred vision occurred in one patient each. From May 1991 to January 1993, 11 recurrences (9 %) were determined.

Atrial flutter

Atrial flutter is a symptomatc arrhythmia because of its high heart rate at rest or during exercise. Atrial flutter has been divided into a common and uncommon types dependent on the morphology and the rates of the flutter waves. Common form (type I) is characterized by rapid atrial activity (approximately 300 beats/min) and "sawtooth" waves in leads II, III and aVF. Uncommon form (type II) is characterized by a predominantly positive flutter in the inferior ECG leads with a faster rate (350 to 430 beats/min) [35].

It is showed that in the common type of atrial flutter, atrial activation appears to be counterclockwise, with caudocephalad activation of the low septum and left atrium and cephalocaudad activation of the free wall of the right atrium [36]. The recording of endocardial atrial activity in human flutter allowed to identify a zone with fragmented and prolonged electrograms in the low posteroseptal right atrium (slow conduction area) [37]. These findins strongly suggest that atrial flutter originates in the right atrium, and, more precisely, in its lower portion near coronary sinus orifice and that is due to a reentrant mechanism. So, ablation of the myocardial isthmus between the inferior vena cava and tricuspid valve may be may interrupt atrial fibrillation and prevent recurrences [38].

Radiofrequency ablation of this area has led to successful termination of arrhythmia in approximately 50-60 % of patients [39-40]. In our institute, seven patients underwent radiofrequency catheter ablation for the treatment of intractable atrial flutter. A line of block was created from the coronary sinus mouth to the inferior vena cava and from the coronary sinus mouth to the atrioventricular node for applications of radiofrequency energy. No complication has occurred and the success rate was 40 %.

Ectopic atrial tachycardia

Ectopic atrial tachycardia is an infrequent cause of symptomatic supraventricular tahcycardia. The majority of ectopic atrial tachycardias are due to intra-atrial reentry, but they may be due to enhanced automaticity. In children and young adults with incessant ectopic atrial tachycardia, cardiac dilatation and congestive heart failure may occur that are potentially reversible on control of the arrhythmia [41-42].

Because of the refractoriness of ectopic atrial tachycardia with antiarrhythmic medications, nonpharmacologic therapy is often required. Good candidates for ablation would be patients who have atrial tachycardia with a single P wave morphology not associated wih atrial flutter or fibrillation. First, tachycardia must be carefully mapped from both the right and left atrial regions. Kay et al showed that the site of origin of the tachycardia was in the right atrium in 93 % of patients [43]. In this report, radiofrequency ablation of tachycardia was successful in all patients without any important complication. But during the follow-up period of 9 months, the clinical arrhythmia recurred in 20 % of patients. In our series, five patients underwent radiofrequency ablation for ectopic atrial tachycardia. In four patients (80 %) the arrhythmia was terminated without complication.

Traditionally, patients suffering from supraventricular tachycardia had to face either life-long antiarrhythmic drug treatment or, in cases where drugs failed to control the arrhythmia or were not tolerated, had to undergo surgical intervention. The recent developments of radiofrequency catheter ablation techniques has dramatically changed the management of these patients.

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