Focal Atrial Tachycardias Arising from the Right Atrial Appendage: Electrocardiographic and Electrophysiologic Characteristics and Radiofrequency Ablation


From the Department of Cardiology, Royal Melbourne Hospital, and the Department of Medicine, University of Melbourne, Melbourne, Australia

Focal Atrial Tachycardias Arising from Right Atrial Appendage. Objective: To characterize the electrocardiographic and electrophysiological features and frequency of focal atrial tachycardia (AT) originating from the right atrial appendage (RAA).

Background: The RAA has been described as a site of origin of AT, but detailed characterization of these tachycardias is limited.

Methods: Ten patients (3.8%) of 261 undergoing radiofrequency ablation (RFA) for focal AT are reported. Endocardial activation maps (EAM) were recorded from catheters at the CS (10 pole), tricuspid annulus (20 pole Halo catheter), and His positions. P waves were classified as negative, positive, isoelectric, or biphasic.

Results: The mean age was 39 ± 20 years, nine males, with symptoms for 4.1 ± 5.1 years. Tachycardia was incessant in seven patients, spontaneous in one patient, and induced by programmed extrastimuli in two patients. These foci had a characteristic P wave morphology. The P wave was negative in lead V1 in all patients, becoming progressively positive across the precordial leads. The P waves in the inferior leads were low amplitude positive in the majority of patients. Earliest EAM activity occurred on the Halo catheter in two patients. Mean activation time at the successful RFA site = -38 ± 15 msec. Irrigated catheters were used in six patients, due to difficulty achieving adequate power. RFA was acutely successful in all patients. Long-term success was achieved in all patients over a mean follow up of 8 ± 7 months.

Conclusions: The RAA is an uncommon site of origin for focal AT (3.8%). It can be suspected as a potential anatomic site of AT origin from the characteristic P wave and activation timing. Irrigated ablation catheters are often required for successful ablation. Long-term success was achieved with focal ablation in all patients. (J Cardiovasc Electrophysiol, Vol. 18, pp. 367-372, April 2007)

right atrial appendage, atrial tachycardia, radiofrequency ablation

Introduction

Focal atrial tachycardias (AT) tend to originate from certain anatomic locations in the atria. In the right atrium these sites include the crista terminalis, coronary sinus ostium, tricuspid annulus, and interatrial septum. Anderson et al. defined the right atrial appendage as the pectinated region of the right atrium. It therefore incorporates the entire anterior wall, extending from the crista terminalis posteriorly to the triangulated component anteriorly. Previous studies have identified the right atrial appendage (RAA) as an uncommon site, but information from a series of patients with this tachycardia is lacking. In particular, there is little information regarding the frequency of occurrence of RAA tachycardias, as well as their electrophysiologic and electrocardiographic characteristics. This study describes these features in a consecutive series of patients undergoing radiofrequency ablation (RFA) of focal AT at a single institution.

Methods

Study Population

The study population included 10 patients from a consecutive series of 261 patients undergoing RFA for focal AT. All patients had clinically documented paroxysmal or persistent AT, for which they were having RFA. All patients underwent electrophysiological study after written informed consent was given. Patients were studied in the fasted awake state with minimal use of sedation. All antiarrhythmic medications were ceased a minimum of five half-lives before the procedure. One patient had been taking amiodarone.
Catheter positioning and the approach used in our laboratory for the ablation of focal AT has been previously published. In brief, catheters were positioned in the following manner: (1) CS catheter (10-pole, 2.5-2-mm interelectrode spacing) positioned with the proximal bipole at the ostium of the CS by best septal left anterior oblique projection; (2) Halo catheter (20-pole, 2.5-2-mm interelectrode spacing) positioned around the tricuspid annulus; intracardiac echocardiography (9 MHz) was used to aid positioning of the catheter when necessary; (3) His bundle electrogram catheter; and (4) mapping and ablation catheter.

Standard electrophysiological criteria were used to diagnose AT. If the AT did not occur spontaneously, attempts at induction were made with atrial programmed extrastimulation and burst atrial pacing. If this was unsuccessful, isoproterenol was infused (1 to 6 μg/min). Mapping of the earliest site of endocardial activity relative to the surface P wave was performed with a 4-mm-tip mapping and ablation catheter.

Bipolar intracardiac electrograms were filtered between 30 and 500 Hz, recorded, and stored digitally on a computerized system simultaneously with 12-lead surface ECGs. Offline analysis was performed with the use of on screen digital calipers at 200 mm/second speed.

Mapping of Atrial Tachycardia

Anatomic localization of the atrial focus was performed during tachycardia or atrial ectopy by analysis of: (1) surface ECG P wave morphology, (2) right atrial endocardial activation sequence during tachycardia, and (3) point mapping to locate the site of earliest endocardial activation relative to the surface P wave onset with the mapping/ablation catheter. Anatomic location was determined by right and left anterior oblique fluoroscopic projections (Fig. 1), as well as intracardiac echocardiography when necessary. In all cases, the triangulated component of the appendage was mapped from tip to base and then down to the tricuspid annulus to precisely define the foci location in relation to the RAA. In four patients, in order to facilitate mapping and assessment of anatomic location, CARTO (Biosense Webster, Diamond Bar, CA, USA) electroanatomic mapping or Ensite NavX (St Jude Medical, St Paul, MN, USA) mapping was also performed (Fig. 2).

P Wave Morphology

Surface 12-lead ECG morphology was assessed as previously described. P waves were described on the basis of deviation from baseline during the T-P interval as: (1) positive (+) if there was a positive deviation from the isoelectric
baseline; (2) negative (−) if there was a negative deviation; (3) isoelectric, arbitrarily defined when there was no P wave deviation from the baseline of >0.05 mV; and (4) biphasic if there were both positive and negative (± or −/+ ) deflections from the baseline. P wave amplitudes were measured from the peak to nadir.

Right Atrial Endocardial Activation Sequence

The consistent deployment of a 20-pole Halo catheter around the tricuspid annulus, a decapolar catheter in the CS, and a catheter in the His position allowed characterization of right atrial endocardial activation. Activation timing was measured from the onset of the P wave in lead V1 of the surface ECG (arbitrarily assigned a time of 0 msec) to each of the intracardiac bipoles of these catheters. Activation times were measured in a standardized fashion to the onset of the first rapid deflection from the baseline.

Radiofrequency Ablation and Outcome

Radiofrequency ablation was performed with continuous temperature feedback control of power output to achieve a target temperature of 50–60°C, for a maximum power of 50 W, according to anatomic location of the site of earliest endocardial activity. Open irrigated 4 mm ablation catheters were used with a maximum power of 30 W if adequate power was not achieved with standard ablation catheters. Acute procedural success was defined as the absence of tachycardia or ectopy 30 minutes after ablation and despite the infusion of isoproterenol (up to 6 μg/min) and burst atrial pacing. Follow-up was at one, three, six, and 12 months with clinical assessment and a 12-lead electrocardiogram and at six and 12 months, a 24-hour monitor was performed. If patients experienced symptoms, electrocardiography and 24-hour monitoring were performed.

Statistical Analysis

All variables are expressed as mean ± SD. Fisher’s exact test was used to compare patient group characteristics. A P value <0.05 was considered statistically significant.

Results

Patient Characteristics

Of 261 patients who underwent RFA of 285 ATs, 10 were determined to have an AT arising from the RAA. Nine of the 10 patients were male (mean age 39 ± 20 years; range 19–72 years). Symptoms attributable to tachycardia had been present for 4.1 ± 5.1 years and patients had failed a mean of 1.5 ± 1.0 antiarrhythmic medications. Five patients had developed tachycardia-mediated cardiomyopathy ranging in severity from mild to severe. One patient had an aortic valve replacement. Right atrial size was normal in all patients. No patients had other additional arrhythmias.

Tachycardia Characteristics

In seven patients the AT was incessant. One patient had spontaneous ectopy and in the other two patients, the tachycardia was induced with atrial programmed extrastimuli. Sustained tachycardia was present in all patients with a mean tachycardia cycle length of 516 ± 154 msec. In all patients, atrial tachycardia could be differentiated from atypical AVNRT and a slowly conducting accessory pathway by the presence of persistent or transient AV dissociation.

Anatomic Location

The anatomic location of the RAA tachycardia was from the base of the triangulated component of the appendage in nine patients and from the tip of the appendage in one patient. Tachycardias originating from the base of the triangulated component demonstrated a relatively consistent location at the inferolateral base (Fig. 3).

P Wave Morphology

For AT foci originating from the RAA, the P wave in the precordial leads was characteristic. Lead V1 was negative in all 10 patients, with notching present in six patients. Across the precordial leads the P wave became progressively more positive; however, the extent of precordial evolution was variable (Fig. 4). The P waves in the inferior leads were positive, or had a positive component, in 9/10 patients. Lead I was
positive in two patients and isoelectric/positive in seven patients. Lead aVR was negative or isoelectric in 9/10 patients. Lead aVL had variable morphology.

**Atrial Endocardial Sequence Mapping**

The earliest endocardial activation on the standard catheters (His bundle, Halo, and CS) occurred at the Halo catheter in all patients. The mean activation times to P wave onset were as follows: His bundle 24 ± 28 msec; proximal CS 55 ± 29 msec; distal CS 90 ± 32 msec; distal Halo 25 ± 34 msec; mid Halo 8 ± 17 msec; proximal Halo 40 ± 16 msec. The characteristic atrial endocardial activation sequence is demonstrated in Figure 5. In general, for tachycardias arising from the RAA, activation was earliest at 10:00 to 11:00 o’clock on the tricuspid annulus. This was followed by proximal and distal activation of the Halo catheter, then His and proximal CS activation.

**Radiofrequency Catheter Ablation**

Mapping for the earliest endocardial activity was performed during tachycardia (nine patients) or with atrial ectopy (one patient). RFA was acutely successful in all 10 patients. At the site of successful ablation, the endocardial atrial activation preceded the onset of the P wave by a mean of 38 ± 14 msec. The electrogram at successful sites was complex and fractionated in two patients. The mean number of radiofrequency applications was 17 ± 12. When RFA was performed during tachycardia, the time to termination at the successful site was 7 ± 3 seconds. At the site of successful ablation, “speeding” occurred in nine patients and deceleration of tachycardia before termination in one.

In seven patients, successful ablation was performed using irrigated tip ablation catheters. In five of these patients, ablation was commenced with nonirrigated 4-mm tip ablation catheters; however, irrigated-tip ablation catheters were subsequently employed due to difficulty achieving adequate power. The other patient had a failed ablation at another institution and the case was commenced with an irrigated-tip ablation catheter. In the final patient, the case was commenced with an irrigated tip ablation catheter.

The mean procedure time was 121 ± 45 minutes and the fluoroscopy time was 29 ± 12 minutes. There were no procedural complications.

**Follow-Up**

Of the 10 patients successfully ablated, one patient had a recurrence following the initial procedure. A repeat procedure was performed with successful ablation using an irrigated-tip catheter at the site of the original ablation at the base of the RAA. One patient with a cardiomyopathy...
had normalization of left ventricular function following successful ablation. Long-term success was achieved in all patients off antiarrhythmic medication over a mean follow-up of 8 ± 7 months.

**Discussion**

Despite the right atrial appendage being a recognized site for the origin of focal atrial tachycardias, the characteristics of these tachycardias have not been well described. In the present series, the RAA was the site of origin in 10 of 261 (3.8%) patients undergoing RFA for focal AT from all sites and represented 4.7% of AT arising from the right atrium. These tachycardias have a characteristic P wave morphology and can be ablated with a high success rate using standard mapping tools. Due to difficulty achieving adequate power, irrigated-tip catheters are usually required for successful ablation.

**Prior Studies**

Previous studies have reported cases of focal AT arising from the RAA, but due to the limited numbers of patients, it is difficult to determine the electrocardiographic and electrophysiologic characteristics of the tachycardias. From our series, focal RAA tachycardias comprise 3.8% of all focal AT. This is consistent with some series, but others have reported a much higher frequency. The current series is the largest series of focal atrial tachycardias that has described the anatomic location and may therefore be most representative.

**P Wave Morphology**

P wave morphology is a useful guide for the localization of focal AT. All the patients in the current study had a negative P wave in lead V1, with the majority also having low amplitude positive P waves in the inferior leads. While this morphology was characteristic of AT from the RAA, it is not exclusive to this region. AT arising from the tricuspid annulus and the low crista terminalis show a similar morphology in lead V1, although P waves from the low crista terminalis tend to have negative P waves in the inferior leads. Kistler et al. reported six patients with focal AT arising from the superior tricuspid annulus. All had a negative P wave in lead V1, with four having positive or biphasic P waves in the inferior leads. The similarity of P waves from the RAA and the superior tricuspid annulus is not unexpected, due to their close anatomic proximity and the limited spatial resolution of P waves. Tang et al. reported four ATs from the RAA. All had positive P waves in the inferior leads, with lead V1 negative in two patients and biphasic in two patients.

**Activation Mapping and Radiofrequency Ablation**

In all patients the earliest endocardial activity was recorded on the Halo catheter. However, earliest endocardial activity on the halo was ahead of P wave onset in only one patient. Mapping in the trabeculated right atrium can be challenging, as the presence of the pectinate muscles can impair catheter maneuverability. Low blood flow when the catheter is in between two trabeculae can limit power delivery. This may be compounded by relatively low blood flow in the right atrial appendage. In this study, five patients had inadequate power delivery with a standard ablation catheter and irrigation was required. This requirement for irrigation is relatively unique to this region, as it less usual to have inadequate power delivery at other sites in the atria. We have preferred irrigated-tip catheters over larger ablation tip sizes for mapping AT, as the smaller bipole provides greater precision in mapping.

In this study, the base of the triangulated component was the predominant site of origin of focal AT arising from the RAA. This is consistent with previous studies; however, the reason for this propensity is unclear. The topography of the trabeculated right atrium is complex and dominated by the extensive pectinate muscles. This complex geometry has been shown to influence wave propagation and may also be involved in the formation of conduction block and the initiation of reentry. Triggered activity has also been suggested as mechanism of focal AT from the RAA.

**Atrial Tachycardia from the RAA**

In this cohort of patients, nine out of 10 patients were male. This proportion is significantly higher when compared to the rest of our patients with focal AT (P < 0.001), in whom only 35% were male. The reason for this propensity in males is unclear. There was no significant difference between the age of patients with focal AT from the RAA and patients with focal AT from other sites. In this study, eight out of 10 RAA tachycardias occurred spontaneously, with seven of these patients presenting in incessant tachycardia. This is consistent with previous reports. The incessant behavior of the tachycardia appears to be unique to the RAA and explains the high prevalence of tachycardia mediated cardiomyopathy (five out of 10 patients) in this group. Of the other 251 patients who underwent focal AT procedures at our institution, only 2–5% of patients had incessant tachycardia. Interestingly, the only other site with a high proportion of incessant tachycardia was the left atrial appendage with three out of three patients presenting with incessant tachycardia.

**Conclusion**

The RAA is an uncommon site of origin for focal AT. It should be suspected as a potential anatomic site from the P wave morphology and atrial endocardial activation sequence. Irrigated-tip ablation catheters are frequently required to achieve adequate power delivery in this region. Long-term success can be achieved with focal ablation.

Acknowledgments: We would like to thank Dr. Chris Briggs for his assistance with the provision of the anatomic specimens.

**References**


