Ectopic atrial tachycardias with early activation at His site: radiofrequency ablation through a retrograde approach

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Aims The purpose of this study was to evaluate a retrograde approach for radiofrequency (RF) ablation of ectopic atrial tachycardias (EATs) with an early atrial activation at the His site.

Methods and results This study included 12 patients with EAT. During tachycardia, earliest atrial activation was recorded at the His site at a standard catheter setting. Activation mapping was performed in the right atrium and along the mitral annulus and at the aortic root after retrograde insertion of the ablation catheter over the ascending aorta. In five patients, earliest atrial activation was recorded at the mitral annulus (in two patients at the superior-lateral annulus and in three patients at the inferior-medial annulus). In four of these patients, EAT could be successfully treated by RF ablation through the retrograde approach, whereas in one patient, a transseptal puncture was performed in order to achieve a stable catheter position. In seven patients, RF ablation at the non-coronary aortic sinus eliminated the tachycardia. During a follow-up period of 14 ± 8 months, there was no tachycardia recurrence.

Conclusion In patients with EATs and early atrial activation at the His site, tachycardia may arise in the non-coronary aortic sinus or from the mitral annulus. Radiofrequency energy ablation can be performed through a retrograde approach in the majority of these patients and is safe and effective in eliminating this type of tachycardia.

KEYWORDS
Ectopic atrial tachycardia; Non-coronary aortic sinus; Mitral annulus; Radiofrequency ablation

Introduction

Ectopic atrial tachycardia (EAT) is a relative seldom cause of narrow QRS-complex tachycardias (~10–15%). The focus of the tachycardia is commonly in the crista terminalis,1,2 near the tricuspid or mitral annulus,3,4 around the pulmonary veins,5 and at the septal regions.6,7 In this study, we evaluated a retrograde approach for the ablation of EATs with the earliest atrial activation at the His bundle (HB) at a standard catheter setting.

Methods

Study population

The study population included 12 of 145 consecutive patients undergoing electrophysiological study and radiofrequency (RF) ablation for focal atrial tachycardia. All patients had documented paroxysmal or persistent EAT. Eleven patients were highly symptomatic, and one patient was completely asymptomatic but had a permanent EAT with a frequency of 140 bpm and a continuously deteriorating left ventricular ejection fraction. All patients were refractory to at least one anti-arrhythmic medication.

Electrophysiological study

After giving informed consent and withdrawal of all anti-arrhythmic drugs in the last 4 days (no patient was on amiodarone), all patients underwent an electrophysiological (EP) study under sedation with 2.5–7.5 mg of midazolam.

Four catheters were introduced into the right high atrium, right ventricular apex, HB, and in the coronary sinus (CS) via the femoral veins. If the patient was in sinus rhythm at the beginning of the study, high right atrial decremental stimulation was started in order to induce tachycardia. If tachycardia could not be induced, programmed stimulation at a basic cycle length (CL) of 500 and 400 ms with up to two extrastimuli was used. If necessary, a bolus of orciprenalin (0.1–0.4 mg) was given intravenously.
Ectopic atrial tachycardia was defined as: (i) atrial activation starting at a small area from which it spreads centrifugally; (ii) range of activation time less than the tachycardia CL; (iii) a distinct isoelectric line between the P-waves in all 12 leads of surface electrocardiogram; and (iv) ventriculo-atrial dissociation during ventricular pacing at the CL of the EAT without the change of atrial activation sequence.

P-wave morphology
The P-wave morphology was visually evaluated and on the basis of the consensus between two observers. The P-waves were described on the basis of the deviation from baseline during the T-P interval as being: (i) positive if there was a positive deviation from the isoelectric baseline; (ii) negative if there was a negative deviation; (iii) biphasic if there were both positive and negative deflections from baseline; and (iv) isoelectric, arbitrarily defined when there was no P-wave deviation from baseline of ≥0.05 mV².

Mapping of atrial tachycardia
Two patients presented with a sustained EAT during EP study. In the other 10 patients, EAT could easily be induced by atrial stimulation. Tachycardia-CL was 435 ± 62 ms (range 360–510 ms). After induction of the tachycardia, activation mapping was performed via a 7-F 4 mm tip ablation deflectable catheter (Biosense Webster, Inc., Diamond Bar, CA, USA). Activation time was measured from the onset of the local electrogram to the atrial electrogram at the proximal pole of CS electrode. Initial mapping was always started in the right atrium (RA) and included the inferior part of superior caval vein, crista terminalis, the para-His region, the ostium of the CS, the tricuspid annulus, the posterior wall, and the septal region. If atrial activation was not clearly compared with atrial activation at the His region earlier, mapping of the left atrium (LA) was performed at the mitral annulus through retrograde insertion of mapping catheter via the ascending aorta. The location at the mitral annulus was defined by (i) fluoroscopy: the catheter tip had to demonstrate the characteristic motion which is synchronized to the motion of the CS catheter in both the right anterior oblique (RAO) and left anterior oblique (LAO) fluoroscopic views and (ii) the presence of a ventricular electrogram >0.5 mV.

The catheter was then pulled back to the aortic root. All three sinuses of the aortic valve and the proximal segment of the ascending aorta, where atrial potential was present, were carefully mapped. If necessary, a transseptal puncture was performed and the LA was mapped including the mitral annulus, left atrial appendage, the roof, the posterior wall, the pulmonary veins, and the septal region.

Radiofrequency catheter ablation
Radiofrequency energy was delivered at the site of the earliest atrial activation under continuous fluoroscopy (30 W, upper temperature limit 55°C, and 40–60 s). If tachycardia did not terminate in 10 s or the catheter was dislodged, RF delivery was stopped. The arrhythmia origin was defined by the site of successful ablation, i.e. termination of tachycardia in 10 s after the beginning of RF ablation and no inducibility of the tachycardia during a waiting time of 45 min. After successful ablation, AH-, HV-interval and both antegrade and retrograde conduction properties of the AV node were evaluated.

Follow-up
After the procedure, rhythm monitoring was performed for 48 h. Transthoracic echocardiography was performed the day after the procedure. The patients received 100 mg aspirin orally for 4 weeks. Mean follow-up was 14 ± 8 months.

Statistical analysis
Data are expressed as mean ± SD.

Results
Mapping and ablation of the tachycardia
At the standard catheter setting, earliest atrial activation was registered at the HB area and activation of CS occurred from proximal to distal in all patients (Figure 1). Atrial activation at the HB occurred 3 ± 9 ms before the onset of the P-wave and 15 ± 5 ms before the reference CS electrogram. In 10 patients, mapping of the RA showed a later activation at all sites compared with the HB area and to the onset of the P-wave. The local electrograms at the earliest RA site were registered at the immediate proximity of HB electrode and included a distinct His potential. No ablation was attempted at this site. In two patients, earliest atrial activation in the RA was registered at the inferior intra-atrial septum (8 and 12 ms earlier than P-wave onset). The application of three RF ablations at this site failed to terminate tachycardia.

In five patients, earliest atrial activation was registered at the mitral annulus: in three patients at the inferior-medial annulus (~7 o'clock at the LAO projection on fluoroscopy and activation time 41 ± 15 ms) and in two at the superior-lateral annulus (~2 o'clock in the same projection and activation time 46 ± 18 ms) (Figure 2A). Atrial activation at the non-coronary aortic sinus of the aortic valve occurred 16 ± 8 ms later than that at the mitral annulus, left and right aortic sinuses were activated 3 ± 5 and 5 ± 7 ms later than non-coronary aortic sinus, respectively. Activation mapping of the mitral annulus could be performed in all five patients through the retrograde approach. In four patients, EAT terminated in 1.4 ± 2 s after RF ablation was started (Figure 2B). In one patient, catheter tip was unstable at the inferior-medial mitral annulus. For that reason, a transseptal puncture was performed and a long Fast Cath SL1 sheath (St Jude Medical, St Paul, MN, USA) was introduced in the LA. Activation mapping of the LA verified the inferior-medial mitral annulus as the site of earliest activation. The tip of the ablation catheter had a stable position at this site, and EAT terminated 6 s after RF ablation was started.

In seven patients (including the two patients with an early atrial activation at the inferior intra-atrial septum), the earliest atrial activation at the mitral annulus was registered inferior-medially, but it was late compared with the CS reference electrogram (16 ± 8 ms) and the onset of P-wave (23 ± 8 ms). In these patients, mapping of the aortic sinus demonstrated an early activation in the non-coronary aortic sinus (55 ± 15 ms) followed by activation of the right (15 ± 10 ms) and left aortic sinuses (13 ± 15 ms). Non-coronary aortic sinus activation occurred 33 ± 9 ms earlier than atrial activation at the HB (Figure 3A). In all three aortic sinuses, tip of the ablation catheter had a very stable position and this was confirmed by fluoroscopy and the stable morphology of local electrograms. The application of RF energy in the non-coronary aortic sinus terminated tachycardia within 3 s in five patients and within 8 s in all patients and rendered it non-inducible for the next 45 min in all patients (Figure 3B). A mean of 3 ± 2 RF applications was required to successfully ablate tachycardia. After successful ablation, the ablation
Figure 1  From top to bottom: electrocardiogram leads I, II, III, aVL, V1, and V6. Intra-cardiac electrograms: high right atrium, proximal and distal His (HIS p and HIS d), coronary sinus distal to proximal (CS 1-2 to CS 7-8), and distal and proximal poles of the right ventricular apex electrode (RVA d and RVA p). Common activation pattern for all 12 patients: during tachycardia, distal His catheter registrates the earliest atrial activation, followed by proximal His, proximal coronary sinus, and high right atrium. The coronary sinus is activated from proximal to distal.

Figure 2  (A–D). From top to bottom: electrocardiogram leads I, II, III, aVR, V1, and V6. Intra-cardiac electrograms: high right atrium (HRA, d: distal pole, p: proximal pole), distal and proximal His (HIS d and HIS p), coronary sinus distal to proximal: (CS 1-2 to CS 7-8), tip of the ablation catheter (ABL d), and distal and proximal poles of the right ventricular apex electrode (RVA d and RVA p). (A) The tip of the ablation catheter (Abl) is placed at the inferior-medial mitral annulus (C, D) and registrates a local atrial activation 20 ms earlier than distal His activation. (B) Radiofrequency energy application at this site terminates the tachycardia in 0.7 s.
A catheter was left in place and a ‘pig tail’ catheter was introduced retrogradely in the aorta ascendens through a second arterial sheath placed in the left femoral artery. An aortography was performed in the RAO and LAO projection and confirmed that the site of successful ablation was the non-coronary aortic sinus (Figure 3C and D). After successful ablation, there was no change in AH and HV intervals and antegrade or retrograde conduction properties of the AV node in any patient. In six patients, a selective coronary angiography was performed and excluded stenosis or spasm in proximal coronary arteries. In one patient, a 50% stenosis of the middle segment of the left anterior descending artery was revealed.

Follow-up
During a follow-up period of 14 ± 8 months, all 12 patients remained asymptomatic. A 24 h Holter monitoring was performed in 10 patients at 3 and 6 months after ablation and showed sinus rhythm without any pathological tachycardias. No patient has been taken any anti-arrhythmic drugs during follow-up.

P-wave morphology
In all five patients in whom EAT originated at the mitral annulus, the P-waves in the precordial leads had a biphasic morphology with a first negative and a second positive component (Figure 4A and B). The morphology of the P-waves in the patients with EAT arising from the non-coronary aortic sinus is shown in Table 1.

Discussion
Main finding
This study shows that EATs with the earliest atrial activation at His catheter at a standard catheter setting might originate from the non-coronary aortic sinus or at the mitral annulus, especially, if activation mapping during tachycardia identifies the His region as the site of earliest right atrial activation. Ablation of these tachycardias can be done safely through a retrograde approach, thereby omitting the need for a transseptal puncture.

Activation sequence and radiofrequency ablation
Ectopic atrial tachycardias originating from the non-coronary aortic sinus and in the proximity of mitral valve annulus have been described previously. Both types of atrial tachycardias are characterized by a proximal to distal activation of the CS and earliest activation of the RA recorded at the His region. Generally, the sequence of biatrial activation during a focal atrial tachycardia depends on the location of the arrhythmogenic focus, conduction velocity of the atrial myocardium, the presence or absence of anatomic barriers, and the presence of pathways of preferential conduction between the two atria. Such inter-atrial electrical connections have been shown to be the Bachmann’s bundle, the region of the fossa ovalis and the CS musculature. Sakamoto et al. described in their canine pacing study that the distance from the pacing site to each of the insertion sites of inter-atrial muscular
connections in the ipsilateral atrium was the primary determinant in the selection of preferred conduction pathway. The exact location of the arrhythmogenic focus in EATs that can be successfully ablated in the non-coronary aortic sinus is not known. The non-coronary aortic sinus lies anterior and superior to the paraseptal region of the left and right atria. Its rightward margin is adjacent to the epicardial aspect of the right atrial myocardium, and its leftward margin is adjacent to the epicardial aspect of the left atrial myocardium. The thickness of atrial myocardium at these sites is not more than 2–3 mm. For that reason, the origin of the EAT directly from the epicardium of the RA or LA adjacent to the non-coronary aortic sinus would be expected to break-through to the endocardium of the correspondent atrium simultaneously or immediate after registration of the atrial potential in the non-coronary aortic sinus. In our study, we found that activation of the RA endocardium occurred always later than in the non-coronary aortic sinus. In our study, a mapping of LA was not performed in any of the patients with this type of EAT. However, Ouyang et al.\textsuperscript{9} have found that the earliest LA activation was consistently later than that in the RA by 2–5 ms in all their patients. This excludes a left atrial epicardial origin. The focus of this type of tachycardia might be located either in the non-coronary aortic cusp or in the space between non-coronary aortic cusp and atrial epicardium. Murine embryological studies have shown the presence of specialized conduction system retro-aortically in early stages and a marked regression in later developmental stages.\textsuperscript{16} Incomplete regression may lead to persistence of arrhythmogenic substrate dorsal to the aortic root, explaining the efficacy of RF ablation from non-coronary aortic sinus. Early atrial activation at the His site might be explained by the presence of muscular connections between the focus of EAT and the HB region. Yamada et al.\textsuperscript{17} reported on a patient with EAT originating from the non-coronary aortic cusp for whom RF ablation around the HB and at the mid-inter-atrial septum in the LA led to a change in the activation in the CS: the initial proximal to distal CS activation changed to a middle to proximal and distal CS activation after RF energy application to the roof of the CS ostium and to a distal to proximal CS activation after further ablation around the HB region and to the anterior aspect of the mid-inter-atrial septum in the LA. Ectopic atrial tachycardia could be finally successfully ablated in the non-coronary aortic sinus. This case report provides strong evidence for the presence of direct muscular connections between the focus of the tachycardia and the HB region.

In all five patients with EAT arising from the mitral annulus (in three patients at the inferior-medial annulus and in two patients at the superior-lateral annulus), the earliest right atrial activation was at the His site and the CS was activated from proximal to distal. Kistler et al.\textsuperscript{4} reported on seven patients with EAT arising around the superior-lateral aspect of the mitral annulus. Similar to our patients, earliest right atrial activation was registered at the HB, and CS activation was earlier proximally than distally. These findings suggest that during EAT arising from the mitral annulus, electrical activation propagates over preferential pathways between the LA and RA, leading to an earlier activation of the RA at the His site and proximal CS, than in inter-atrial septum and distal CS. Roithinger et al.\textsuperscript{13} have shown that during pacing from the LA, the putative insertion site of Bachmann’s bundle and the fossa ovalis are the preferential pathways for conduction to the RA. In our patients, conduction over Bachmann’s bundle could explain the characteristic right atrial activation. Preferential conduction over the fossa ovalis is not likely, as this would have led to an earlier activation of the right side of inter-atrial septum when compared with the HB. In three of our patients, the focus of the EAT could be successfully ablated at the inferior-medial mitral annulus (between 6 and 8 o’clock in the LAO 45° projection). To the best of our knowledge, this localization has not been previously described for EATs arising from the mitral annulus and underscores the necessity of mapping this part of annulus if this type of tachycardia is suspected.

Left atrial tachycardias are usually mapped and ablated through a transseptal approach. Left-sided accessory pathways can be mapped and ablated at the mitral annulus through a retrograde approach.\textsuperscript{18} We have shown that EATs also arising from the mitral annulus can be mapped and in the majority of the cases also successfully ablated after retrograde introduction of the ablation catheter in the LA over the aorta ascendens and left ventricle.

Ectopic atrial tachycardias originating from the triangle of Koch and the vicinity of the atrioventricular node have been described.\textsuperscript{19} Although CS activation during this type of
tachycardia has not been explicitly described, it can be assumed that activation pattern of these tachycardias at the standard catheter setting would be similar to the EATs which we have described in our work, i.e. earliest atrial activation at the His site and proximal to distal activation of the CS. The aortic bulbus has not been mapped in any of these patients. Radiofrequency ablation at the inter-atrial septum could successfully terminate tachycardia, but in the majority of the patients, an HB potential was registered at the site of successful ablation at the right side of inter-atrial septum and a junctional rhythm occurred during ablation. A mean value of 10 ± 6 RF applications was required for elimination of the tachycardia. It cannot be excluded that at least in some of these cases, the arrhythmogenic focus would have been eliminated from the non-coronary aortic cusp with less RF applications (in our study 3 ± 2 applications) and without the risk of damaging the HB.

P-wave morphology

In our study, we could not identify any P-wave characteristics that were invariably present in all patients. P-wave in EATs arising from the mitral annulus had a characteristic biphasic pattern, with a negative component followed by a positive one. In accordance with the findings of Kistler et al., 4 the initial negative component was more prominent than the positive component from lead V2 up to V6 in all five patients.

The P-wave morphology in the seven patients with EAT arising in the non-coronary aortic sinus was also variable. P-wave was positive in lead I in four patients, whereas in the other three patients it was negative, isoelectric, and isobiphasic, respectively. In their study, Ouyang et al.9 found a positive P-wave in lead I in all nine patients with this type of EAT, but according to our data, this is not an invariable P-wave morphological characteristic. The variability of P-wave morphology is probably explained by different preferential conduction of the EAT from non-coronary aortic sinus to the LA and RA, leading to variable activation patterns.

Conclusion

In patients with EAT and early activation at the HB, the possibility that tachycardia may arise in the non-coronary aortic sinus or from the mitral annulus should be strongly considered. Radiofrequency energy ablation can be performed through a retrograde approach in the majority of the patients and is effective and safe in eliminating this type of tachycardia.

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References


