Risk and benefits of radiofrequency catheter ablation at the aortic cusp for the treatment of para-Hisian supra-ventricular tachyarrhythmias

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Risk and benefits of radiofrequency catheter ablation at the aortic cusp for the treatment of para-Hisian supra-ventricular tachyarrhythmias

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ABSTRACT

Risk and benefits of radiofrequency catheter ablation at the aortic cusp for the treatment of para-Hisian supra-ventricular tachyarrhythmias

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Background The risk and benefit of radiofrequency catheter ablation (RFCA) at the aortic cusp (AC) for the treatment of supraventricular tachyarrhythmia (SVT) has not yet been studied.

Methods We performed RFCA at the AC in 19 patients (male 64.7%, 46.9±21.9 years old) with para-Hisian SVTs (12 atrial tachycardias [AT], 7 atrioventricular reciprocating tachycardia [AVRT]), and analyzed the prevalence, electrophysiologic findings, clinical outcome, and compilation risk.

Results 1. Among 113 patients with AT, 13 patients had para-Hisian AT and 12 patients (8.8%, 53.4±19.8 years old, 58.3% female) underwent successful ablation from non-coronary cusp (NCC; n=10), right CC (RCC; n=1) or left CC (LCC; n=1) without complication (3.1±2.3 times RF delivery). During 19.7±9.8 months of follow-up, AT recurred in a patient with multiple foci. 2. Among 580 patients with AVRT, 27 patients had a para-Hisian bypass tract (BT; 4.7%), and 7 of them (1.1%, 2 pre-excitation syndrome, 5 concealed BT) were successfully ablated at NCC (n=2) or RCC (n=5) (7.0±7.1 times RF delivery). Among 5 patients with AVRT successfully ablated at RCC, one patient developed complete heart block 48 hours after procedure, and 2 patients recurred AVRT or delta-wave in ECG during 13.9±11.7 month follow-up.

Conclusion Catheter ablation within NCC is an effective procedure to eliminate para-Hisian SVTs. However, RFCA on RCC has a risk of heart block

sometimes.

Key words : aortic cusp, supraventricular tachycardia, atrial tachycardia, catheter ablation

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I. INTRODUCTION

Most arrhythmias induced by automaticity or triggered activity originate from embryologic raphe structures such as a junction between a vessel and the myocardium or between an annulus and the myocardium.[1] Atrial fibrillation (AF) is commonly triggered by the ectopies from a junction between the left atrium (LA) and pulmonary vein,[2] and right ventricular outflow tract ventricular tachycardia (VT) sometimes originates from a junction between pulmonary artery and pulmonary valve.[3, 4] Coronary sinus ostium is a common site of ectopic atrial tachycardia,[5] and some VTs originate from the aorto-mitral continuity.[6] An aortic cusp (AC) is one of embryologic raphe structures and an excellent target for catheter ablation of some VTs originating from the left ventricular outflow tract (LVOT) because it allows good contact and stable position of the catheter.[7, 8] However, radiofrequency catheter ablation (RFCA) of supra-ventricular tachyarrhythmias (SVTs) is rarely performed at the AC in patients with atrial tachycardia (AT)[9, 10] or atrioventricular reciprocating tachycardia (AVRT).[11-15] Therefore, we hypothesized that the AC can be an appropriate target for RFCA in patients with para-Hisian SVTs, including AT and AVRT. The purpose of this study was to evaluate the prevalence, effectiveness and risk of RFCA at the AC for the treatment of para-Hisian SVTs.

II. MATERIALS AND METHODS

Patients selection

The study protocol was approved by the Institutional Review Board. All patients provided written informed consent. There were 113 patients with AT, 580 patients with AVRT, and 320 patients with AF. Among them, we included 19 patients who underwent RFCA at the AC for SVT in this study. The mean age was 46.9±21.9 years old, and 64.7% were male patients.

Electrophysiological mapping

Intracardiac electrograms were recorded using a Prucka CardioLab™ Electrophysiology system (General Electric Health Care System Inc., Milwaukee, WI, USA). A decapolar catheter (Bard Electrophysiology Inc. Lowell, MA, USA) was positioned in the high right atrium (RA), and a duo-decapolar catheter (St. Jude Medical Inc., Minnetonka, MN, USA) was inserted via the femoral vein and positioned inside the coronary sinus (CS) and the low RA. A quadripolar catheter was also placed in the His bundle recording region. We induced tachycardia by programmed electrical stimulations. After documenting narrow QRS tachycardias, differential diagnosis was performed by atrial or ventricular extra-stimulations, atrial or ventricular entrainment pacing, or para-Hisian pacing. In cases with para-Hisian AT or AVRT, we mapped the right mid-septum first, and then the left mid-septum after performing a trans-septal puncture with Schwartz left (SL) 3 sheath (St. Jude Medical Inc., Minnetonka, MN, USA). If both right and left mid-septum were not appropriate for mapping or RF energy delivery due to the risk of heart block, ascending aortogram was performed in the left anterior oblique (LAO) 35° and right anterior oblique (RAO) 35° views with a 5Fr pig tail catheter (6 Fr, A&A Medical Device Inc. Gyeonggi-do, Republic of Korea; power injection of contrast media 25 mL/sec), and then AC was mapped. In a patient who underwent AT ablation at the AC after AF ablation, 3-dimensional (D) electroanatomical mapping (CARTO-XP, Johnson & Johnson Inc. Diamond Bar, CA, USA) was performed.

Radiofrequency catheter ablation at AC

We conducted AC ablation in patients who satisfying following criteria: 1) visible His potential at potential target site on both right or left mid-septum, 2) failed 3 trial of RF energy delivery at right or left side mid septum with a risk of heart block, or 3) the best target site on AC without visible His potential after mapping of right and left side septum. After confirming the locations of AC and ostia of the right and left coronary arteries, we mapped the target site of tachycardia at the same fluoroscopic angle to the ascending aortograms. We mapped each AC with a 7Fr quadripolar 5 mm-tip deflectable ablation catheter (Boston Scientific Inc. USA.), and delivered RF energy to the potential target sites (50W, 60°C, for 60 sec; Stockert generator, Biosense Webster Inc.; Diamond Bar, CA, USA.). To minimize the risk of heart block, we paced the high RA with 400~500ms by monitoring the AH interval for prolongation or for junctional ectopic rhythm during RF energy delivery (Figures 1C and 4C). In 2 patients with paroxysmal AF, AT originated from the non-coronary cusp (NCC) was sustained after bi-atrial ablation and electrical isolation of 4 pulmonary veins. In one of the patients, we localized the AT focus on the AC and His potential recording area with 3D electroanatomical mapping (CARTO-XP, Johnson & Johnson Inc. Diamond Bar, CA, USA), and successfully ablated it (Figure 2). In the other patient, AT was successfully ablated at AC with conventional mapping. After successful catheter ablation, we measured the distances between the target ablation site and right or left coronary artery ostia in RAO 35° and LAO 35°, respectively.

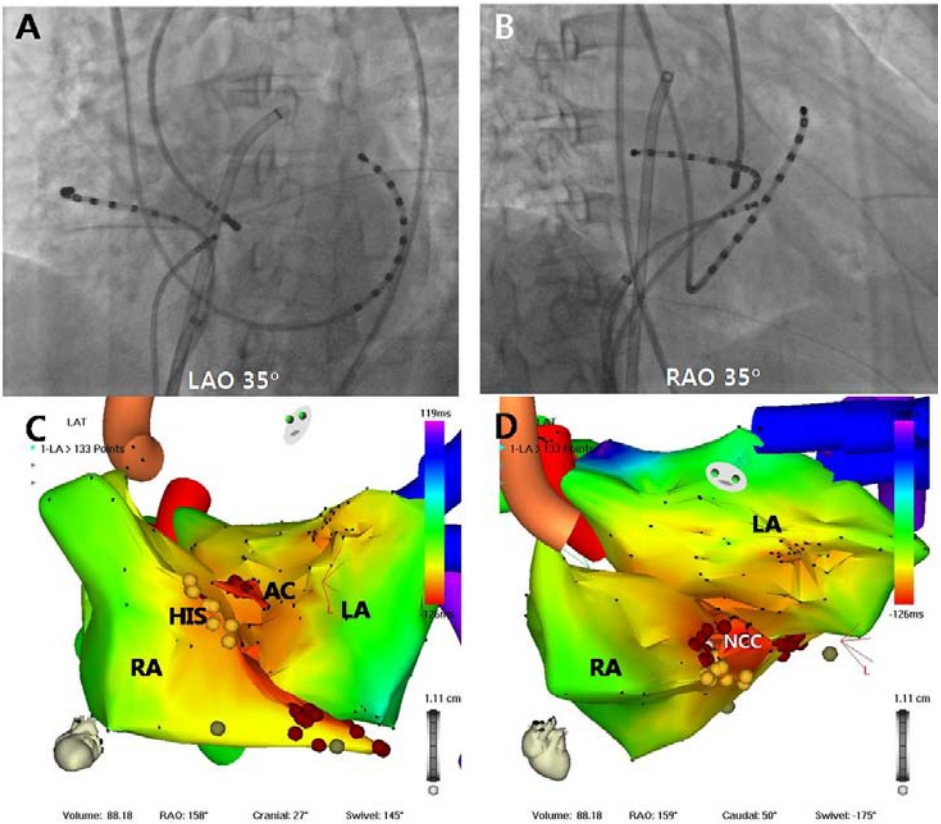

Figure 2

Patient follow-up

Patients were asked to visit the outpatient clinic 1, 3, 6, and 12 months after RFCA for follow-up. Electrocardiography (ECG) was performed at every visit, and Holter ECG and/or their event recorder was evaluated 3 months after RFCA or at anytime the patient reported palpitations. Patients were also advised to call a clinician or visit the outpatient clinic whenever they experienced symptoms suggestive of an arrhythmia.

Data analyses

We evaluated the ECG characteristics, successful ablation sites, time from local electrogram to P wave onset, RF delivery time, complication, and clinical outcome. All values were expressed as the mean±SD.

III. RESULTS

Characteristics of AT of AC origin and clinical outcome after RFCA

Table 1. Characteristics of AC originated AT

Case #	Sex	Age (yr)	Arrhythmia	ABL Site	Time to P wave	RF #	Time to Success	Complication	FU duration	FU Result
1	F	69	AT	NCC	-55	2	8	None	34	SR
2	F	47	AT	NCC	-38	4	11.2	None	31	SR
3	F	33	AT	NCC	-32	4	5.3	None	28	SR
4	F	30	AT	NCC	-56	3	3.7	None	27	SR
5	F	12	AT	NCC	-42	1	6.5	None	23	SR
6	M	77	AT, multifocal	NCC	-33	2	5.9	None	19	Recur
7	F	69	AT	NCC	-48	3	10.1	None	9	SR
8	M	53	AT	NCC	-41	1	4.7	None	8	SR
9	M	68	AT/PAF	RCC	-36	1	3.9	None	5	SR
10	M	53	AT	LCC	-35	4	8	None	16	SR
11	M	70	AT/PAF	NCC						
12	F	60	AT/AVNRT	NCC	-25	9	0.4	None	17	SR
M		53.42			-40.09	3.09	6.15		19.73	
SD		19.76			9.66	2.3	3.08		9.77	

Among 113 patients who underwent RFCA for AT (41.7±17.6 years old, 49% female), 13 patients had AT of para-Hisian septal origin, and 12 patients (8.8%, 53.42±19.76 years old, 58.3% female) underwent successful ablation at the AC (Figure 3A). Table 1 summarizes the clinical and electrophysiologic characteristics of AC originated ATs. Most patients underwent successful ablation of AT at the NCC (n=10), but there was a patient with a right coronary cusp (RCC) originated AT and a patient with a LCC originated AT. The two patients were associated with paroxysmal AF (Table 1). One of them was found with AV nodal reentrant tachycardia. The other patient had 3 different foci of AT: NCC, low crista, and coronary sinus ostium. All these patients underwent AT ablation as the last step of the procedure after ablation of other tachy-arrhythmias.

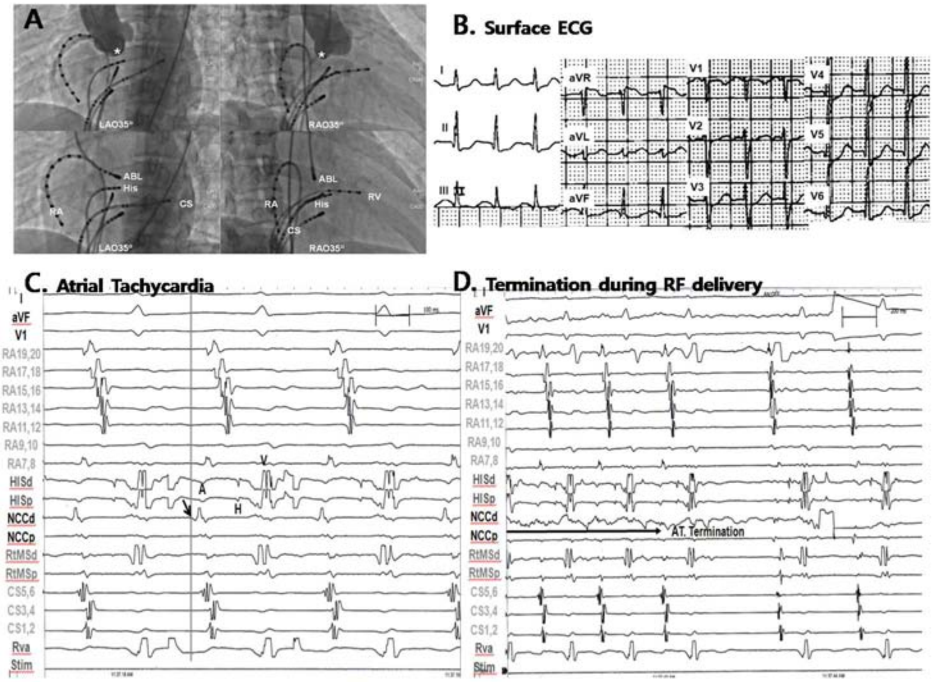

Figure 1

In patients whose AT was suspected to have originated from an AC, we took ascending aortograms in RAO 35^o and LAO 35^o views to locate the AC and ostia of coronary arteries after right and left septal mapping (Figure 1A). In those patients, surface 12 lead ECG showed flat and ambiguous axis of P waves (Figure 1B), and lined up sequence of both RA and LA electrograms (Figure 1C). The mean tachycardia cycle length was 349.0±19.1 ms. As shown in Figure 1A, the NCC was located on the atrial side of the LA, and was the most common successful ablation site of AC originated AT. At the successful ablation site, the activation time difference between the mapping catheter and P wave onset was 40.1±9.6 ms, clearly earlier than the septal A signal in His bundle recording (Figure 1C). The mean number of radio frequency application was 3.1±2.3 times, and the ablation time to successful termination was 6.2±3.1 sec (Figure 1D). The distance from the coronary artery ostium to the target ablation site (AC) was 13.5±4.5 mm in RAO 35^o and 19.2±7.1 mm in LAO 35^o. There was no transient heart block or any other complication. During 19.7±9.8 month-long follow-up, one patient with multiple AT foci recurred, and her tachycardia was managed with medical treatment. However, we could not exactly locate the focus of the recurred AT because we did not perform redo-ablation.

Characteristics of AVRT successfully ablated at AC and clinical outcomes after RFCA

Table 2. Characteristics of AVRT successfully ablated from AC

Case #	Sex	Age (yr)	Arrhythmia	ABL Site	AP potential	RF #	Time to Success	Complication	FU duration	FU Result
1	M	54	CBT	NCC	-	3	11.5	None	35	
2	M	31	WPW	NCC-RCC	-	1	2.9	None	23	
3	M	41	CBT	RCC	-	18	15.7	AVB	10	
4	M	12	CBT	NCC	-	12	7.2	None	7	
5	M	72	CBT	RCC	-	1	5.3	None	4	AVRT recur
6	M	11	WPW	RCC	-	1	9.2	None	3	Delta recur
7	M	29	AVRT	RCC		13	12	None	15	
M		35.71				7.00	9.11		13.86	
SD		22.06				7.14	4.36		11.61	

Among 580 patients with AVRT (37.5±15.2 years old, 68% male) who underwent RFCA, 27 (4.7%) patients had para-Hisian bypass tract (BT), and 7 (1.2%) of them were ablated at AC (Figure 3B). Two of them presented pre-excitation syndrome (WPW), and the other 5 were found with concealed bypass tract (CBT).

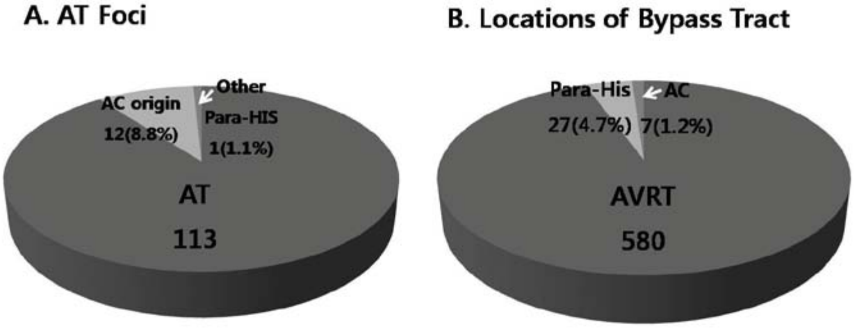

Figure 3

Table 2 summarizes the clinical and electrophysiological characteristics of AVRT successfully ablated at AC. All 7 patients were male. Five of them underwent ablation at the RCC, and the 2 others at the NCC. The mean tachycardia cycle length was 302.0±80.4 ms. In patients with para-Hisian BT, the locations of AC and the relationship with the ostium of coronary arteries were confirmed with ascending aortogram at the fixed fluoroscopic angles (RAO 35° and LAO 35°, Figure 4A). The distance from the coronary artery ostium to the target ablation site, AC, was 24.0±10.1 mm and 21.9±5.8 mm in RAO 35° and LAO 35° view, respectively. We confirmed the location of the BT with ECG and endocardial contact mapping (Figures 4B and 4C).

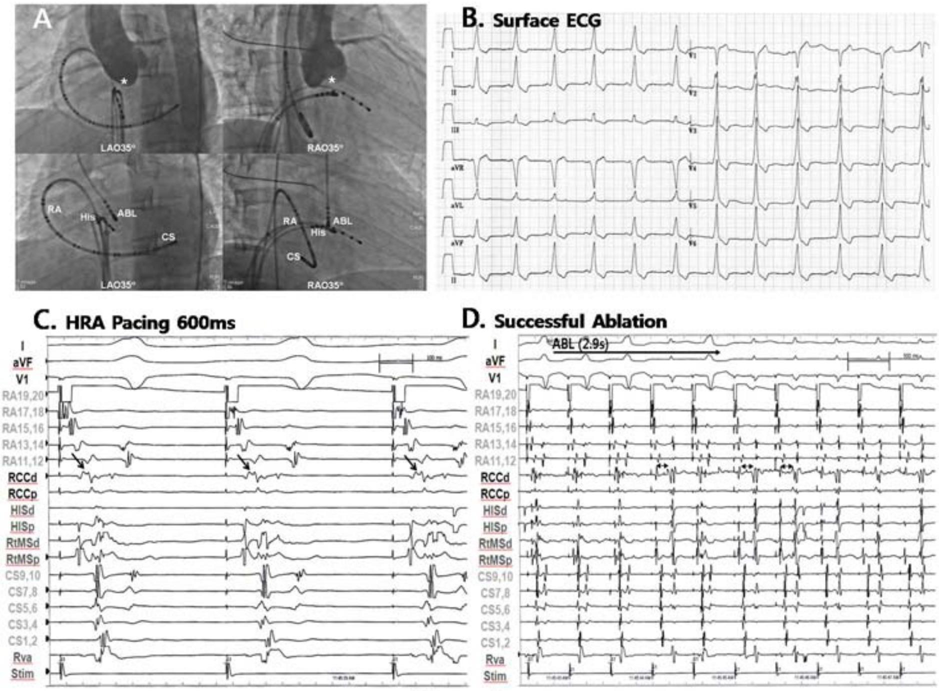

Figure 4

Both the right and left side His bundle potentials were recorded just beneath the RCC (Figure 5A). Sometimes, we delivered ventricular extra-stimulation to separate A and V signals and to examine whether His potential existed in the AC before RF energy delivery in patients with pre-excitation. In most patients, a near-field accessory pathway potential was observed on the mid-septum below AC, but clear His bundle potential was simultaneously observed. In contrast, accessory potential recorded from the AC was far-field potential without showing sharp His potential (Figure 5).

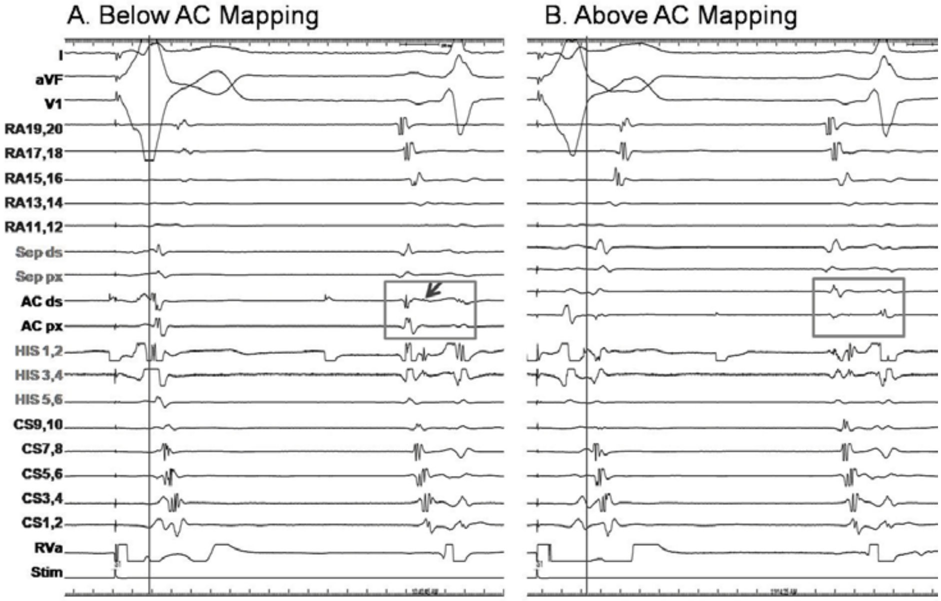

Figure 5

In 2 patients with pre-excitation, RFCA was performed during high RA pacing 500ms to detect potential heart block as early as possible (Figure 4D). The mean number of RF energy delivery was 7.0±7.1 times, and the mean RF energy delivery time to successful ablation was 9.1±4.4 sec. We achieved acute success in all 7 patients. However, complete heart block appeared in a patient with WPW syndrome 48 hours after successful ablation (patient #3 in Table 2). AVRT recurred in one patient with CBT (patient #5 in Table 2), and delta wave appeared again on surface ECG without AVRT in patients #6 (Table 2). All 3 patients with complication or recurrence underwent RFCA at the RCC.

IV. DISCUSSION

In this study, we demonstrated that the AC might be an effective alternative target for both para-Hisian AT and AVRT. AT originated from the AC was mostly localized to the NCC, but para-Hisian BTs were commonly mapped on the RCC. Although catheter ablation of SVTs from the NCC was safe and effective, RF energy delivery to the RCC had a risk of heart block or high chance of recurrence as it requires RF energy to be very cautiously and limitedly delivered.

Prevalence of AC origin arrhythmias

Since the beginning of the new millennium, catheter ablation of VT from the AC has been reported[7, 8, 16, 17] as an alternative approach to the outflow tract VT. Kanagaratnam et al.[18] and Ouyang et al.[8] reported successful ablation of VTs of AC origin in 12 patients (18%) and 15 patients, respectively. Sekiguchi et al.[4] also reported successful ablation of VT or VPCs from the AC in 11 patients (8.7%) of 127 patients. AT of AC origin has been reported by researchers, including our group, but most of the publications were case reports.[19-25] However, Das et al.[21] reported that 7 of 54 patients (13.0%) who underwent invasive electrophysiologic study for ectopic AT had successful ablation from the AC. Ouyang et al.[23] reported 9 cases of successful ablation of para-Hisian AT from the NCC, which accounted for 4.1% of patients who underwent focal AT ablation. In the present study, AT was successfully ablated from the AC in 8.8% of the patients who underwent catheter ablation of AT. Therefore, the operator's awareness of the AC as a potential target for catheter ablation of AT might be important when treating patients with para-Hisian AT. Recently, RFCA of AF became a common procedure, and AT of AC origin has been identified during AF ablation.[20, 26] Among our patients, 2 out of 12 patients were incidentally found with AC originated AT during AF catheter ablation. In terms of BT ablation at the AC, our study is the first to report RFCA performed at the AC in patients with para-Hisian AVRT.

Anatomical consideration of AC

Embryologically, neural crest cells contribute to the formation of the aortico-pulmonary septum, outflow tract endocardial cushion, and isolation of His-bundle from the myocardium. Epicardium derived cells (EPDC)[27] transform the myocardium into fibrous tissue. After looping of the heart tube, EPDC continues to form 4 rings (sinoatrial ring, atrioventricular ring, primary ring, and ventriculoatrial ring) developing cardiac conduction system.[28] Therefore, myocardial extensions[29] to the aorta or pulmonary artery and AV junctional cells[30, 31] distributed around the annulus and atrial roof may contribute to the formation of arrhythmogenesis.

The aortic valve (AV) is located at the center of the heart, contacting with the pulmonary valve, mitral and tricuspid annulus, His bundle, both atria, and both ventricular outflow tracts. As shown in Figure 2, the His bundle region is adjacent to the posterior right side of the RCC and the anterior right side of the NCC, connecting the atrium and ventricular myocardium through the central fibrous body.[23, 32] The right margin of the NCC is in contact with the RA, and the left margin of NCC is with the LA. Therefore, the NCC can be an alternative target for catheter ablation when accessing and ablating from both sides of the septum fails or is not appropriate due to the existence of His bundle potential. Sometimes, RFCA of para-Hisian BT beneath the RCC or at the junction between the RCC and the NCC may have a risk of heart block.

Risk and benefits in catheter ablation of AC origin SVT

Catheter ablation of SVT at the AC by a supra-valvular approach has several merits in terms of effectiveness. First, this approach is appropriate in cases for which it is difficult to conduct bi-atrial septal mapping due to poor accessibility or risk of heart block. Second, a retrograde aortic approach to AC ensures catheter stability with good contact and limited catheter motion during RF energy delivery. Third, RF energy may penetrate deep into the inter-atrial or inter-ventricular septum through the AC. However, AC ablation has a risk of collateral damages such as aortic valve damage, coronary artery injury or spasm, thrombo-embolic events, or heart block. Hachiya et al. [17] reported the use of low power and low temperature RF energy setting. In our study, we used usual RF power and temperature setting (50W, 60°C) for AC ablation after experience of AC origin VT recurrence with low power RF ablation, There was no evidence of aortic valve damage in post-procedure follow-up echocardiography in 37 patient experiences so far. AT and BT were usually eliminated within 10 sec, if the target site was on the right spot. To prevent thrombo-embolic complications after RFCA, we used aspirin for 1 month. To prevent heart block, we chose the target site without His bundle potential confirmed by separating A and V signals with extra-stimulation, or we performed rapid atrial pacing during RF energy delivery. If an appropriate target site cannot be mapped without His electrogram, it might be better to use safer technology such as cryo-ablation. We experienced a case of heart block 48 hours after RFCA at the RCC. In this case, we delivered RF energy for 18 times and the time to successful ablations was also long (15.7 sec). Although we delivered RF energy above the AC, it seems to have penetrated deep into the tissue and resulted in a delayed collateral damage.

Study limitations

This study included a highly selected group of patients referred for catheter ablation, and the number of patients was also limited. This study was not randomized to compare the effectiveness and risk of direct mid-septal ablation and AC ablation. Although aortogram taken at the fixed fluoroscopic angles can be used to estimate the location of ablation catheter or each AC by referencing bony structures and other catheters, it has limitation in respiratory variations. Real-time intracardiac ultrasound might overcome this limitation and localize near-field His bundle electrogram. We did not evaluate the mechanism of tachycardia by adenosine responsiveness, the proper ablation site with unipolar electrogram, or the optimal power of RF energy for safe ablation. However, isoproterenol (1-3μg/min) was effective in inducing and maintaining para-Hisian AT. Septal AT is relatively common tachycardia after AF ablation, and we do not know the frequency of AC origin AT during AF ablation.

V. CONCLUSION

Catheter ablation within the NCC is an effective procedure to eliminate para-Hisian AT or AVRT. However, RFCA at the RCC has a risk of heart block or recurrence.

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ABSTRACT(IN KOREAN)

상심실성 빈맥의 치료에 있어 대동맥 첨판에서의 고주파 카테터 절제술의 위험성과 장점

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배경 상심실성 빈맥(SVT; supraventricular tachycardia)의 고주파 카테터 절제술(RFCA; radiofrequency catheter ablation)의 위험성과 장점에서 대해서는 지금까지 알려진 바가 많지 않다.

방법 우리는 19명의 히스 주변부(para-Hisian) 상심실성 빈맥(12명의 심방 빈맥, 7명의 방실 회귀성 빈맥)을 가진 환자(남성64.7%, 46.9±21.9세)에서 고주파 카테터 절제술을 시행하였으며, 이들의 유병률, 전기생리학적 특징, 임상적 결과 및 부작용과 관련한 위험성에 대해 분석하였다.

결과 1. 심방빈맥(AT; atrial tachycardia)을 가진 113 명의 환자 중에서, 13명이 히스 주변부 심방 빈맥을 보였으며, 이중 12명의 환자(8.8%, 53.4±19.8세, 여성58.3%)가 대동맥 첨판(AC; aortic cusp)의 심장동맥과 무관한 판막(NCC; non-coronary cusp, 10명), 오른 심장 동맥 판막 (RCC; right coronary cusp, 1명), 왼 심장동맥 판막(LCC; left coronary cusp, 1명)에서 부작용 없이 3.1±2.3회의 고주파 절제술이 성공적으로 시행되었다. 19.7±9.8 개월의 경과 관찰 기관 동안 여러 개의 부정맥 초점을 가지고 있던 한 명의 환자에서 심방 빈맥이 재발되었다. 2. 방실 회귀성 빈맥(AVRT; atrioventricular reciprocating tachycardia)을 보이는 580명의 환자에서 27명은 히스 주변부의 방실 우회로(para-Hisian bypass tract, 4.7%)를 보였으며, 그 중 7명은 (1.1%, 2명의 조기흥분 증후군, 5명의 숨은 방실 우회로) 심장동맥과 무관한 대동맥 판막(2명), 오른 심장동맥 판막(5명)에서 7.0±7.1 회의 고주파 절제술을 시행하여 성공적으로 우회로를 절제하였다. 반면, 오른 심장동맥 판막에서 성공적으로 고주파 절제술이 시행된 5명의 방실 회귀성 빈맥 환자 중 1명은 시술 48시간 후 완전 방실 차단이 발생하였으며, 13.9±11.7 개월의 경과 관찰기간 동안 2명에서 방실 회귀성 빈맥이나 델타파형이 재발하였다.

결론 심장 동맥과 무관한 대동맥 판막에서의 카테터 절제술은 히스 주변부 상심실성 빈맥을 치료하는데 효과적이다. 반면에 오른 심장 동맥 판막에서의 고주파 카테터 절제술은 완전 방실 차단을 발생할 수 있는 위험을 가지고 있다.

핵심되는 말 : 대동맥 첨판, 상심실성 빈맥, 심방 빈맥, 카테터 절제술