Original article

Recurrent atrial tachycardia and atrial fribrillation after circumferential pulmonary vein ablation: What's the difference?

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Keywords: *atrial fibrillation* · *catheter ablation* · *pulmonary vein*

Background Recurrent atrial tachyarrhythmia (ATa) after circumferential pulmonary vein ablation (CPVA) includes atrial tachycardia (AT) and atrial fribrillation (AF). However, whether there are some differences in clinical course and mechanisms between the recurrent AT and the recurrent AF remained unclear. This study was conducted to investigate the incidence, mechanism, clinical course of the recurrent AT and AF in patients under CPVA.

Methods One hundred and thirty consecutive patients (M/F = 95/35) with highly symptomatic and multiple antiarrhythmic drugs (AADs) refractory paroxysmal ($n = 91$) or persistent ($n = 39$) AF were included. The ablation protocol consisted solely of two continuous circular lesions around the ipsilateral pulmonary veins (PV) guided by CARTO system. The endpoint of CPVA is PV isolation. For patients with recurrent ATa within 2 months after the initial procedure, cardioversion with direct current was attempted if the ATa lasted for more than 24 hours. A repeat ablation procedure was performed only for patients with AADs refractory recurrent ATa and at least followed up for 2 months after the initial procedure.

Results Within 2 months after the initial procedure, 52 patients (40.0%) had experienced episodes of symptomatic recurrent ATa. Among them, 23 patients (44.2%) with recurred AT alone (AT group), 14 patients (26.9%) with recurred AF alone (AF group), and 15 patients (28.8%) with recurred AT and AF (AT plus AF group). The delayed cure rate (65.2%) in AT group was significant higher than that in AF group (21.4%, $P < 0.05$) and AF plus AT group (26.7%, $P < 0.05$). A repeat ablation was performed in 21 patients, including 6 patients with recurrent AT alone, 8 patients with recurrent AF alone, and 7 patients with recurrent AF plus AT. The mean number of PV gaps was 1.2 ± 0.4 in AT group, which was significantly lower than that in AF group (2.6 ± 0.7, $P < 0.05$) and AF plus AT group (2.0 ± 0.6, $P < 0.05$). Delayed cure rate and number of PV gaps between AF group and AF plus AT group were comparable ($P > 0.05$).

Conclusions Present study indicates that recurrent AT and AF after CPVA have the different clinical course and different electrophysiological findings during repeat procedure as follows: (1) After CPVA, spontaneous resolution of recurrent ATa was mainly found in patients with recurrent AT alone (about two thirds patients). (2) The type of recurrent ATa after CPVA is associated with the number of PV gaps.

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Circumferential pulmonary vein ablation (CPVA) is an effective strategy for treating patients with atrial fibrillation (AF).[1-3] However, recurrent atrial tachyarrhythmia (ATa) after CPVA is a common event with incidence ranged from 16% to 46%.[4-8] Recurrent ATa includes atria tachycardia (AT) alone, AF alone, or AF plus AT. Both recurrent AT and recurrent AF demonstrate a tendency to spontaneous resolution during continuous follow up.[9-12] Whether there are differences in mechanism and clinical course between the recurrent AT and the recurrent AF remained

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unclear. Present study was initiated to investigate the incidence, mechanism, clinical course of the recurrent AT and AF in patients underwent CPVA.

METHODS

Patient characteristics

From September 2004 to June 2005, 130 consecutive patients (M/F = 95/35) with highly symptomatic and multiple antiarrhythmic drugs (AADs) refractory paroxysmal (n = 91) or persistent (n = 39) AF underwent CPVA guided by three-dimensional (3-D) electroanatomical mapping system (CARTO, Biosense-Webster, USA). The mean age, AF history, left atrium (LA) size and left ventricular ejection fraction (LVEF) of these patients were (57.9 ± 11.5) (24 – 79) years, (7.1 ± 5.7) (0.3 – 30) years, (37.7 ± 5.7) (28 – 55) mm and (66.7 ± 6.43) (54 – 78)%, respectively. Fifty-one patients (39.2%) had concomitant hypertension and structural heart disease.

Mapping and ablation

AADs except amiodarone were discontinued for at least five half-lives before the ablation procedure. After providing written informed consent, each patient underwent electrophysiological study and CPVA in deep sedation state with continuous infusion of propofol. A quadripolar catheter was positioned within coronary sinus for atrial pacing and signal reference via subclavian vein entry. Two 8-F long sheaths (SL1, St. Jude Medical, USA) were advanced to the LA using a modified Brockenbrough technique. After trans-septal catheterization, intravenous heparin was administered to maintain an activated clotting time (ACT) of 250 to 300 seconds. Also, the trans-septal sheaths were flushed with continuous injection of saline (20 ml/h). The technique of CPVA guided by 3-D LA mapping have been described previously in detail.[3,13] Briefly, after PVs was outlined via angiogram, LA geometry was reconstructed using CARTO system with a 3.5 mm tip ablation catheter (Navi-Star, Thermcool™, Biosense-Webster, USA). PV antrum was identified by venography in conjunction with endocardial electrograms and tagged on the CARTO map. Continuous irrigated radiofrequency (RF) ablation was performed along the PV antrum to encircle the ipsilateral PVs with a target temperature of 43℃ and maximum power of 35 W. One decapolar circumferential mapping catheters (Lasso, Biosense-Webster, USA) was placed within the left or right superior PV for monitoring the PV potentials during ablation. Procedural end-point was completeness of circular lesions and electrical isolation of all PVs. If a typical atrial flutter (AFL) was documented before the procedure, and a macro-reentrant AT was induced after CPVA or spontaneously occurred during ablation, the critical isthmus responsible for this tachycardia was identified and ablated.

Post-ablation management and follow-up

All patients received one of AADs, which was discontinued after the first month if no recurrent ATa occurred. Low molecular heparin and warfarin were administered during the first 3 days after the procedure, but discharged only on warfarin and international normalization ratio (INR) was maintained between 1.8 – 2.5. Warfarin was withdrawn 3 months later if no symptomatic ATa was detected. All patients were followed up with 12-lead electrocardiography (ECG), 24-hour holter recordings at 2 weeks, 1, 3, 6, 9 and 12 months after ablation. Also, monthly telephone interviews were conducted in all patients. Any episode of symptomatic ATa, regardless of duration, was considered as arrhythmia recurrence. For patients with recurrent ATa within 2 months after the initial procedure, cardioversion with direct current was attempted if the ATa lasted for more than 24 hours. A repeat ablation procedure was performed only for patients with AADs refractory recurrent ATa and at least followed up for 2 months after the initial procedure.

Repeat ablation procedure

During the repeat ablation procedure, a detailed and complete 3-D mapping of the LA was performed with the use of CARTO system first, then the normal atrial tissue, the low voltage area, and the previous lesion lines were evaluated carefully by the LA voltage mapping. Scar was defined as a bipolar voltage of < 0.1 mV indistinguishable from noise. Gaps were defined as breakthroughs in the previous ablated area and identified by sites with single potentials or fractionated potentials (Fig.). All gaps were closed with segmental RF ablation. After re-isolation of PVs, no additional ablation lines were performed unless the recovered conduction across previous lines occurred. If a macro-reentry AT or focal ATa was induced after PV isolation, ablation energy was delivered at the critical isthmus or the earliest sites. The ablation settings during the repeat procedure was similar to that in initial procedure.

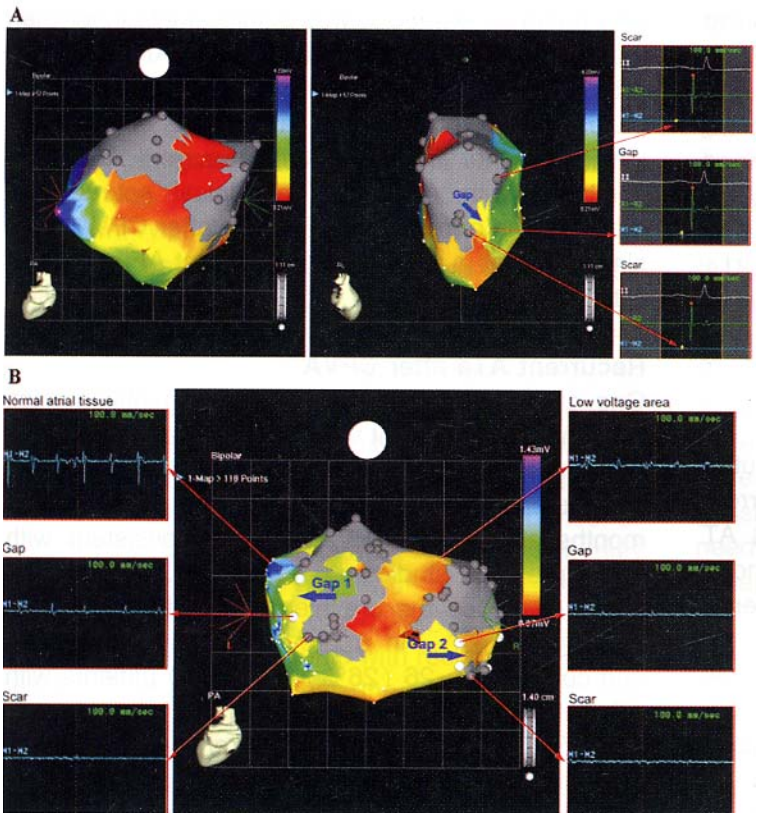

Fig. Three-dimensional electroanatomic CARTO maps of the LA. **A**: 3-D voltage map of LA in a patient with recurrent AT alone. The gray areas represent regions of scar created by the initial procedure. In this patient, no recurrent conduction between the pulmonary veins and the atrium was found in the posterior-anterior (PA) view (left). However, a single gap at right anterior-inferior part of the initial circular lesion was found in right lateral (RL) view (middle). The endocardial bipolar recording at the gap site (arrow) reveals a fractionated potential (right). **B**: 3-D voltage map of LA in a patient with recurrent AF alone. The initial circular lesions around the pulmonary veins was not continuous in the PA view, and 2 gaps at the posterior wall of LA were observed in this patient (middle). Endocardial mapping of multiple sites of LA shows different potentials of normal atrial tissue, low-voltage area, and gap site. The characteristics of gap recoding presented a single potential (left) or fractionated potential (right) in this patient.

Statistics

Continuous variables were expressed as mean ± standard deviation (SD). For comparison of this kind of variables between different groups, analysis of variance (AVOVA) followed by Duncan's correction was applied. Categorical variables were compared by χ^2 or exact Fisher's test. Analyses were performed using the SPSS statistical software (Version 11.5). P value < 0.05 was considered statistically significant.

RESULTS

Ablation results in initial procedure

Complete isolation of ipsilateral PVs were achieved in all patients with a mean fluoroscopy time of (21 ± 6) minutes and a mean procedure time of (162 ± 53) minutes. Cavo-tricuspid isthmus ablation was performed in 15 patients (11.5%) with history of typical AFL. Induced AT and spontaneous AT occurred in 12.3% (16 cases) of patients, 9 of them were PV-LA gap related, 5 of them were cavo-tricuspid isthmus dependent, 2 of them were mitral isthmus dependent and 1 of them was focal origin. Additional liner lesions or focal ablations were created in these patients.

Follow-up outcomes

Within 2 months after the initial procedure, 52 patients (40.0%) had experienced episodes of symptomatic recurrent ATa. Among them, 23 patients (44.2%) with recurred AT alone (AT group), 14 patients (26.9%) with recurred AF alone (AF group), and 15 patients (28.8%) with recurred AT and AF (AT plus AF group). Recurrent arrhythmias in AT plus AF group were mainly AT within the first 2 weeks and AF after 2 weeks. The clinical characteristics of patients with recurrent ATa among the 3 groups were comparable ($P > 0.05$, Table).

Table. Clinical characteristics of patients with recurrent ATa

Variables	AT group (n=25)	AF group (n=19)	AF plus AT group (n=15)
Gender (M/F)	19/6	12/7	10/5
Age (years)	56.9±10.5	54.7±11.4	55.9±10.5
History (years)	6.1±4.7	6.9±5.1	6.8±4.9
AF type (n)			
Paroxysmal	19	13	10
Persistent	6	6	5
HBp and SHD (n)	7	5	4
ECHO			
LA (mm)	37.1±6.1	37.7±5.4	36.7±5.7
LVEF (%)	65.1±5.43	67.0±5.43	66.6±6.03

ATa: atrial tachyarrhythmia; AT: atrial tachycardia; AF: atrial fibrillation; HBp: hypertension; LA: left atrium; ECHO: echocardiography; LVEF: left ventricular ejection fraction; SHD: structural heart disease.

During subsequent follow up, recurrent AT resolved spontaneously in 15 patients (65.2%) in AT group.

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However, the recurrent ATa automatically resolved only in 3 patients (21.4%) and 4 patients (26.7%) in AF group and AF plus AT group respectively ($P>0.05$). The delayed cure phenomena was more commonly observed in patients experienced recurrent AT alone than those experienced AF alone or AF combined with AT ($P<0.05$, for both). The mean time for reaching delayed cure was (40 ± 21) days after the initial procedure. The incidence of delayed cure was 43.3% (22/52) in the present study.

Repeat procedure and results

A repeat ablation was performed in 21 (70%) out of 30 patients with repetitive or persistent recurrent ATa, which included 6 patients with recurrent AT alone, 8 patients with recurrent AF alone, and 7 patients with recurrent AF plus AT. The other 9 patients refused a repeat procedure. During the second procedure, at least one LA-PV gap was observed in all patients except one with typical AFL due to recovered cavo-tricuspid isthmus conduction. The mean number of gaps was 1.2 ± 0.4 in AT group, which was significantly lower than that in AF group (2.6 ± 0.7, $P<0.05$) and AF plus AT group (2.0 ± 0.6, $P<0.05$). The difference of gap number between AF group and AF plus AT group was non-significant ($P=0.1$). All the LA-PV gaps were successfully closed by segmental ablation on the previous circular lines.

After a mean of (139 ± 52) (63 – 254) days of follow-up, 16 patients (76.2%, 16/21) were free of symptomatic ATa after the second procedure. In summary, 116 (89.2%) out of the 130 patients were free of ATa without AADs after the median of 6 months follow up since the last ablation procedure.

Procedure-related complications

Cardiac tamponade occurred in 1 patient during the initial procedure, and stroke occurred in another patient just after the procedure. Both of the complications were treated without long-term sequelae. Right superior PV stenosis (50%) was observed due to a dislodgement of the mapping catheter during ablation in 1 patient. The patient was asymptomatic and demonstrated no evidence of progressive narrowing on spiral CT scan 6 months after the ablation.

DISCUSSION

Main findings

(1) After CPVA, the delayed cure rate in patients with recurrent AT alone was significantly higher than that in patients with recurrent AF or AF combined with AT. (2) The mean number of PV gaps in patients with recurrent AT alone was significantly lower than that in patients with recurrent AF or AF combined with AT. (3) The clinical course and mechanisms of recurrent AF alone after CPVA were similar to that in patients with recurrent AF combined with AT.

Recurrent ATa after CPVA

One of drawbacks of CPVA is the relatively high incidence of recurrent ATa after initial procedure. Present study demonstrated 52 patients (40.0%) had experienced episodes of recurrent ATa within 2 months after initial CPVA, this is consistent with some previous studies.[5-8] However, only limited report described the prevalence of different type of recurrent ATa.[4] In a previous study by Ouyang and co-workers, 26 (26%) out of 100 patients with AF suffered recurrent ATa after CPVA. Majority (80.7%, 21/26) of the recurrent ATa was AT alone in their study. In the present study, 44.2% of patients (23/52) were AT alone, and 55.8% of patients (29/52) were AF or AF combined with AT after CPVA. The incidence of recurrent AT alone in current study is much lower than that from Ouyang et al[4] study with similar technique. The differences between the two studies maybe due to operator experience and/or the duration of follow up. In Ouyang et al[4] study, the redo procedure was performed very early [(52 ± 59) days]. However, we found some patients with recurrent AT within first 2 weeks experienced AF during subsequent follow-up, so we excluded these patients from AT group.

Clinical course of recurrent ATa

It has been demonstrated that some of early (<6 – 8 weeks) recurrent ATa after AF ablation can disappear spontaneously during the further follow-up, so-called "delayed cure" phenomenon.[9-12,14] In consistent with the previous studies, we also found as high as 43.3% (22/52) of patients with recurrent ATa reached a delayed cure. However, no data was available in concern to identify the patients who have a high propensity to delayed cure. In present study, we found the recurrent ATa spontaneously resolved in nearly two-thirds patients with recurrent AT alone, which is significantly higher than that in patients with AF (less than one third). Our result indicates that early re-ablation might not be considered for patients with recurrent ATa, especially for patients with AT alone, but for patients

with AF alone or AF plus AT, a more aggressive strategy (early re-ablation) could be recommended.

Number of gaps and the type of recurrent arrhythmias

Consistent with previous studies, resumption of conduction between LA and PVs due to gaps was found to be the dominant factor responsible for recurrent ATa after CPVA.[4,7,15] However, as far as we know, there were no studies investigating the relationship between the number of PV gaps and the type of recurrent arrhythmia after CPVA. In present study, repeat procedure was carried out in 70% (21/30) of patients with recurrent ATa, and most of the patients (5/6) with recurrent AT alone only had single gap or without gap, but at least 2 gaps distributed on both sides of circular PV lesions were found in 14 out of 15 patients with recurrent AF. The possible explanations that the number of gaps associated closely with the clinical type of recurrent ATa might include: (1) The single conduction outlet and LA substrate modification after initial procedure hinder the rapid PV tachycardia to activate LA, and decrease the degree of LA anisotropy conduction.[16-19] This can partly explain the underlying mechanism responsible for the development of AT. (2) The multiple outlets of PV gap conduction, interaction between right sided and left-sided PVs and local conduction delay might have facilitated fibrillatory conduction in the LA.[20-23] This can be a possible explanation for the development of AF or AF combined with AT after the initial procedure. Our results support the concept that discontinuity of linear lesion can cause arrhythmias.

Number of gaps and delayed cure of recurrent ATa

In present study, delayed cure was mainly observed in patients with recurrent AT alone, not in patients with AF and AF plus AT, therefore, delayed cure of recurrent ATa maybe associate with the number of gaps. We postulate that spontaneous resolution of recurrent ATa is presumably attributed to the tapering off in tissue necrosis and inflammatory reaction caused by ablation application, and the other presumption is ingrowth of fibrosis and elimination of gap(s) along the lesions.[24,25] In patients with multiple gaps, the healing process can be quite slow. This may in part explain the relatively lower delayed cure rate in patients with recurrent AF.

Difference between recurrent AF and AF plus AT

Concerned clinical course, there was no significant difference between the patients with recurrent AF alone and subjects with AF plus AT. Additionally, the difference of average gap number between AF alone group and AF plus AT group was also non-significant. We postulate non-significant difference in gap numbers contributed to explain a similar clinical course observed between the two groups.

Study limitations

This study is limited by relatively small group of patients included, meanwhile, the proportion of redo cases is not enough (70%). Despite of these possible limitations, the findings in present study needs further confirmation in a larger cohort of patients.

In summary, present study indicates that recurrent AT and AF after CPVA have the different clinical course and different electrophysiological findings during repeat procedure as follows: (1) After CPVA, spontaneous resolution of recurrent ATa was mainly found in patients with recurrent AT. (2) The type of recurrent ATa after CPVA is associated with the number of PV gaps.

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