Case Report

Radiofrequency Catheter Ablation of on-going Persistent Atrial Fibrillation Using a Noncontact Mapping System

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We describe a 70-year-old man with persistent atrial fibrillation (AF) lasting for 3 months who underwent radiofrequency catheter ablation (RFCA) during on-going AF under navigation using a noncontact mapping system (NCM). The AF was converted by the RFCA first to a secondary atrial tachycardia (AT) consisting of common atrial flutter during the left atrial (LA) roof line creation, second to a secondary AT consisting of a focal AT originating from the right superior pulmonary vein, third to a secondary AT which rotated around the LA appendage, and finally to an AT consisting of a peri-mitral flutter after the completion of the circumferential pulmonary vein ablation and LA roof line creation. All the ATs were quickly identified by the dynamic activation map constructed with the NCM and subsequent detailed analysis of the virtual unipolar electrograms, and were eliminated by additional RFCA for each AT mechanism identified. The patient has had no recurrence during 10 months of follow-up without taking any antiarrhythmic agents.
(J Arrhythmia 2008; 24: 81–86)

Key words: Atrial tachycardia, Noncontact mapping, Persistent atrial fibrillation, Radiofrequency catheter ablation

Introduction

A stepwise approach has been reported to be effective in eliminating persistent atrial fibrillation (AF), when radiofrequency catheter ablation (RFCA) was begun with circumferential pulmonary vein ablation, and if the AF still persisted, left atrial (LA) roof line creation, endocardial coronary sinus (CS) isolation, intra-CS isolation, and mitral isthmus ablation were then performed until the AF terminated.[1,2] However, it has been reported that AF directly converted to sinus rhythm in a small number of patients, and that the majority of the patients developed secondary atrial tachycardias (AT) during the RF ablation.[3] Those ATs seemed to be due to diverse mechanisms, but little is known about the mechanisms.

The noncontact mapping system (NCM) enabled us to make a quick and easy identification of the AT mechanism irrespective of whether it was focal[4] or reentrant.[5]

Kumagai, et al. reported that the complete isolation of the posterior LA, the "box isolation" method, included all the pulmonary veins without posterior vertical lesions, and was associated with a high clinical success rate for AF ablation.[6] We

Received 28, December, 2007: accepted 7, May, 2008.
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report on a patient with persistent AF in whom the Kumagai box isolation was performed during on-going AF, several secondary ATs occurred, all were identified with NCM, and were eliminated by RFCA for each mechanism identified.

Case Report

A 70-year-old man with a history of cerebral embolism episodes was referred for RFCA of his symptomatic persistent AF that had lasted for 3 months and was refractory to several class I antiarrhythmic agents.

After written informed consent was obtained from the patient, we performed an AF ablation during ongoing AF with no anti-arrhythmic agents, in the fasting state. A multielectrode array (MEA) used with the NCM system (Ensite Array, AF Division, St. Jude Medical, Minnetonka, MN, USA), an 8-mm-tip ablation catheter and 20-pole circular-mapping catheters were introduced into the LA through a long transseptal Mullins and 2 SL0 (AF Division, St. Jude Medical) type long sheaths, which were advanced into the LA by a standard Brockenbrough technique. The circular catheter was positioned at the right superior pulmonary vein (PV), the tip of the MEA was positioned in the LA appendage so as to locate the MEA body in the center of the LA, and the ablation catheter was used as a roving catheter to draw the LA geometry.

The recording and analysis by the NCM was performed according to an established method reported by other researchers, of which the details of the NCM have been described elsewhere.[7] During the review of the recorded data, a high-pass filter setting of 1.0 Hz was used for the isopotential map created by the NCM. Throughout the study, heparin was injected to maintain an ACT of greater than 300 seconds. Radiofrequency (RF) energy was delivered using a 7 Fr. 8-mm-tip ablation catheter in the temperature control mode (Fantasista, Japan Lifeline, Inc., Tokyo, Japan) to achieve a tip-tissue interface temperature of up to 55°C with a maximal energy of 50 W. The duration of each RF pulse was 30 seconds.

When the anterior portion of the left PVs was being ablated during the on-going AF after the LA roof line creation, the AF suddenly first converted to a secondary AT with a cycle length of 258 msec. The dynamic activation map constructed with the NCM during the AT in the LA revealed that the AT originated from the inferomedial LA region, and the subsequent activation split into two major activation wavefronts that traveled through the inferior and anterior LA, respectively, and finally reached the lateral LA (**Figure 1**). Further, the virtual unipolar electrogram at the earliest LA activation site exhibited an rS morphology, indicating that the activation came from the right atrium. Then, a 20-pole electrode catheter was placed along the tricuspid annulus, and an activation rotating around the tricuspid annulus in a counterclockwise direction with a post-pacing interval at the carvotricuspid isthmus equal to the AT cycle length was revealed, indicating that the AT was a counterclockwise common atrial flutter. It was eliminated by a line creation at the carvotricuspid isthmus, and converted to sinus rhythm.

After that, a second secondary AT with a cycle length of 198 msec was induced by rapid pacing from the CS performed with a stimulus strength twice the diastolic threshold and a pulse width of 2 msec using a programmable stimulator (SEC-3102, Nihon Kohden, Japan). The dynamic activation map during the AT revealed that it originated from the right superior PV (RSPV), and the subsequent activation spread out from the anterior antrum of the RSPV to the entire LA (**Figure 2**). The virtual unipolar electrogram at the anterior portion of the RSPV antrum exhibited a QS morphology, and thus, it was confirmed that the activation originated from the RSPV. The anterior antrum portion of the RSPV was then ablated, the AT was terminated, and the posterior portion of the LA was ablated in order to create a complete isolation of the posterior LA like the box isolation advocated by Kumagai, et al.[6]

After the box isolation was completed, a third AT with a cycle length of 232 msec was induced by rapid CS pacing (**Figure 3**). The dynamic activation map during the AT revealed an activation rotating around the LA appendage in a clockwise direction, while two daughter activation wavefronts traveling toward the septal and lateral LA were observed. In the "ridge" region between the LA appendage and left superior and inferior PVs, the activation was observed to proceed in the superior-to-inferior direction at an anterior site to the previous ablation line located at the anterior antrum of the left PVs. Thus, wide RF energy applications were then applied to the "ridge" region and resulted in the conversion to a fourth secondary AT with a cycle length of 229 msec (**Figure 4**).

The dynamic activation map during the fourth AT revealed an activation rotating around the mitral annulus in the clockwise direction while a line of conduction block was present with two colliding activation wavefronts from the septal-to-lateral and lateral-to-septal directions at a site anterolateral to

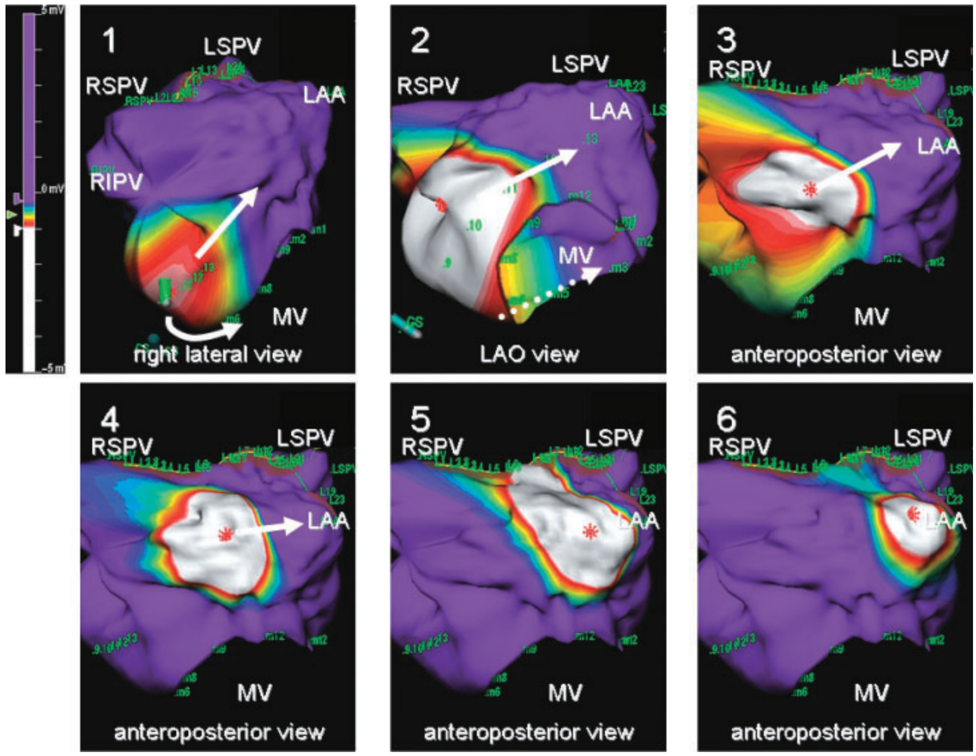

Figure 1 The first secondary AT occurred during the radiofrequency catheter ablation at the anterior portion of the left PVs after the left atrial roof line creation. The panels show the regional dynamic wavefront map constructed with the NCM during the AT. The arrows indicate the direction of the local conduction. LAA, left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; MV, mitral valve; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.

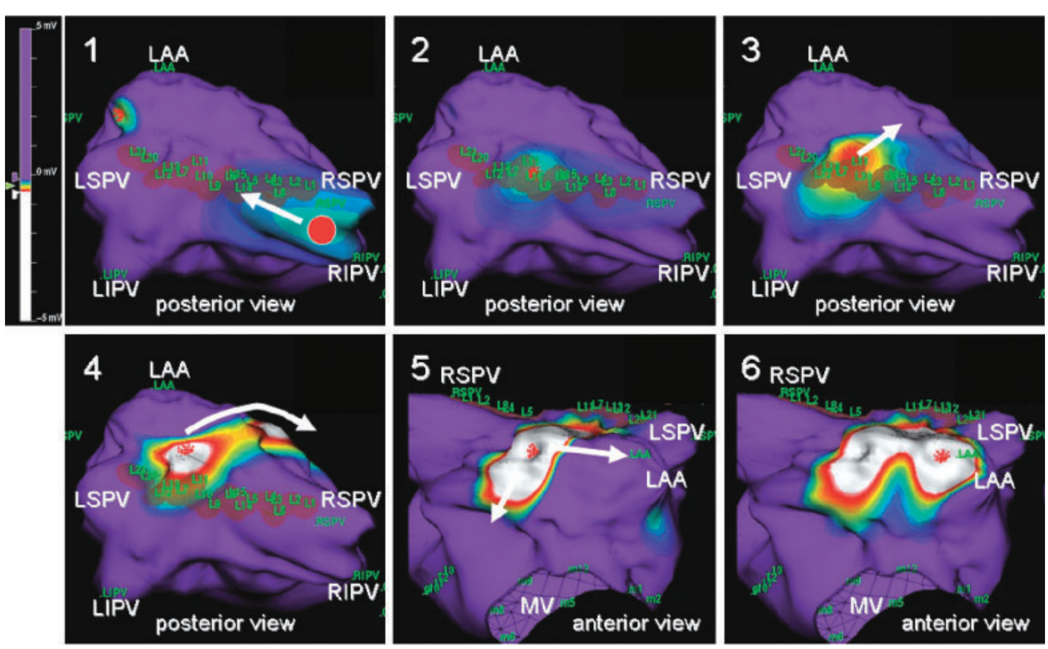

Figure 2 The second secondary AT originating from the right superior pulmonary vein which was induced by rapid coronary sinus pacing after the elimination of the common atrial flutter. The panels show the regional dynamic wavefront map constructed with the NCM during the AT. The arrows indicate the direction of the local conduction. The abbreviations are the same as those in **Figure 1**.

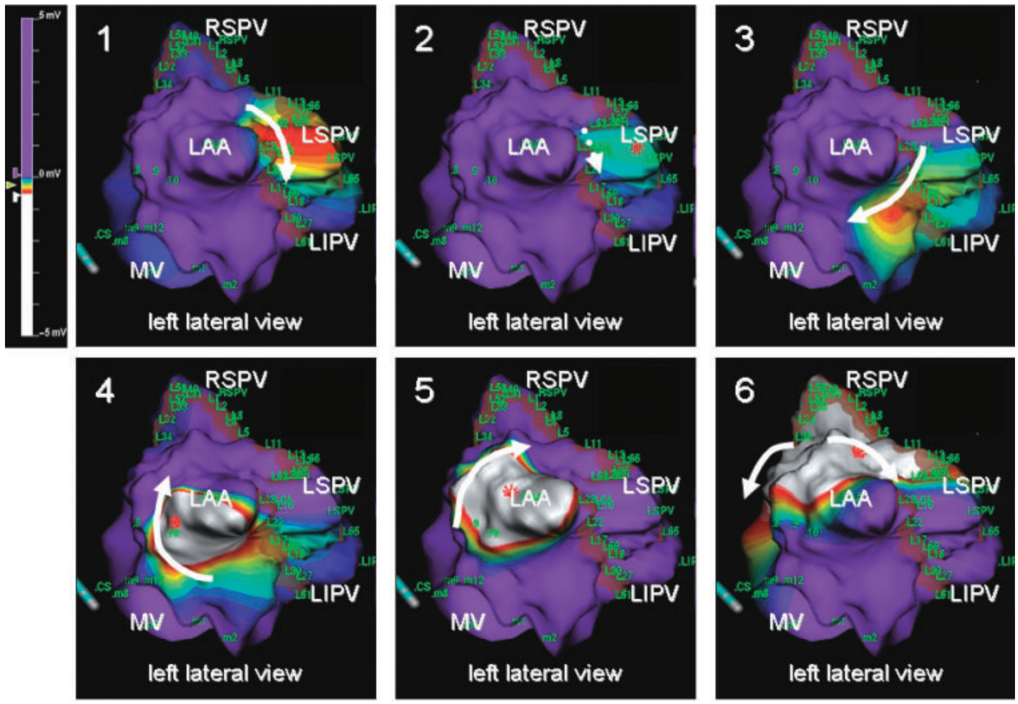

Figure 3 The third secondary AT rotating around the left atrial appendage which was induced by rapid coronary sinus pacing after the Kumagai box isolation. The panels show the regional dynamic wavefront map during the tachycardia, and the regional dynamic wavefront map constructed with the NCM during the AT. The arrows indicate the direction of the local conduction. The abbreviations are the same as those in **Figure 1**.

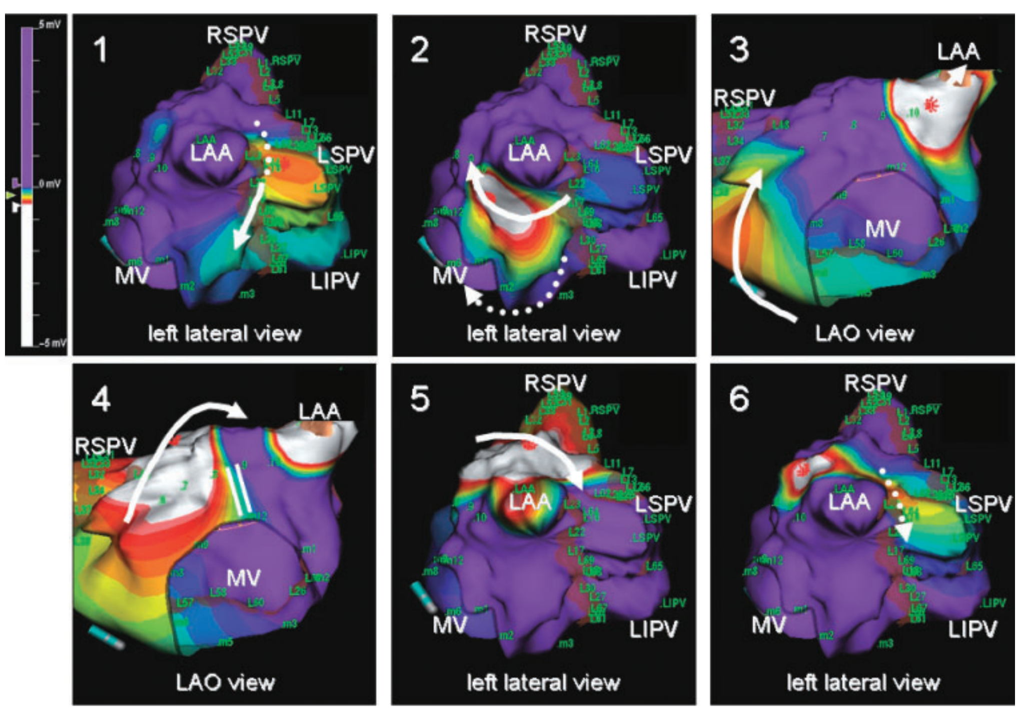

Figure 4 A fourth secondary AT rotating around the mitral annulus occurred after the box isolation. The panels show the regional dynamic wavefront map created during the tachycardia, and regional dynamic wavefront map constructed with the NCM during the AT. The arrows indicate the direction of the local conduction. The double lines indicate the local conduction block. The abbreviations are the same as those in **Figure 1**.

the LA appendage orifice. It was noted that the activation still proceeded to the anterior portion of the ridge, suggesting that the previous wide ablation at that site was not adequate to create local conduction block in spite of having terminated the third secondary AT. To eliminate the AT, a linear ablation was attempted in the mitral isthmus region between the inferolateral mitral annulus and left inferior PV, but it failed to create complete block and terminate the AT. Therefore, another linear ablation was performed from the inferior antrum of the right inferior PV to the posterolateral mitral annulus and the AT terminated by local conduction block at that site. After that, rapid atrial pacing could no longer induce any atrial tachyarrhythmias.

There were no procedure-related complications. The procedure and fluoroscopy times were 237 and 77 minutes, respectively. The patient has been free from any symptoms for 10 months of follow-up without any antiarrhythmic agents.

Discussion

NCM has been reported to be very useful for quickly identifying the AT activation irrespective of whether it is a focal discharge or a reentrant mechanism.[4,5] In this case, 4 secondary ATs with both focal and reentrant mechanisms occurred during Kumagai box isolation, which was performed during on-going AF. With the use of the NCM, all of the secondary ATs were quickly diagnosed and treated based upon each AT mechanism. It was also noteworthy that the completion of a line of conduction block was easily recognized by the NCM, which was very important for the Kumagai box isolation method.

Some aggressive strategies have been developed to ablate AF in an attempt to improve the success rate, and have resulted in a relatively satisfactory outcome, but secondary AT mainly originating from the LA has been reported after PV antrum ablation or circumferential PV isolation with or without additional line creation. The prevalence of the secondary AT has been reported to range from 2.5% to 27%.[8,9] The AT occurring during RF ablation was not always related to the AF or AT recurrence, and it was unclear in the present case whether or not additional RF applications for the secondary AT would have been effective in preventing recurrence. However, ATs with diverse mechanisms have been reported after the AF ablation, which included focal discharge and macroreentrant mechanisms.

AT with a focal discharge mechanism was sometimes reported to originate from the PVs or previously untreated non-PV foci.[10] Those types of AT were usually not difficult to eliminate by additional RF ablation applications because the likely site of the AT origin was the PV with previously isolated but re-connected PV-LA conduction,[11] and thus identification of the AT origin was not difficult even if conventional mapping under fluoroscopic guidance or an electroanatomical mapping system was used. The likely sites of non-PV foci were at the posterior LA, Marshall vein region, peri-ostial region of the PVs and some sites in the right atrium, which were also not difficult to eliminate by RF ablation guided by fluoroscopy or an electroanatomical mapping system.

On the other hand the elucidation of the reentry circuits of AT with a macroreentrant mechanism is usually time-consuming, and their ablation is difficult because they are sometimes transient in nature and multiple in number. Further, even if they are sustained long enough to map, it may take further time to analyze the activation, and the location of the reentry circuits is diverse depending on the case. As mentioned earlier, all the AT with diverse mechanisms were quickly identified and treated by the additional RF ablation applications guided by the activation maps constructed with NCM in this case.

There are some limitations to the analysis using NCM. First of all, NCM cannot correctly record virtual unipolar electrograms in an area >4.0 cm from the center of the MEA. To overcome that issue, efforts should be made to locate the MEA closer (<4.0 cm) to the area of interest including a tachycardia focus or critical site in the reentry circuit. Second, the ventricular repolarization sometimes affects the isopotential maps in the atrium, leading to misunderstanding of the activation. To exclude the effect of the ventricular repolarization, the high pass filter setting should be properly adjusted, or an activation analysis should be done on a beat in which the R-R interval is spontaneously prolonged or atrioventricular conduction is suppressed by an ATP injection or a PVC interpolation. Finally, the amplitude of the virtual unipolar electrogram can be magnified in tube-like structures, "a line of sight issue". To overcome this untoward effect, the geometry-making of such tube-like structures including the pulmonary vein(s) or SVC should be limited to the base portion.

In conclusion, NCM was useful for analyzing the mechanisms of the secondary ATs occurring during the ablation of on-going AF, and the RF ablation under navigation using the NCM was effective in eliminating both the AF and secondary AT in this case.

Acknowledgments

The authors would like to thank Yuuho Iwanaga for his technical assistance.

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