Killing two gaps with a single activation map—Visualization of the precise macroreentrant circuit including the pulmonary vein and left atrium

Hiro Yamasaki, MD, Tomoaki Hasegawa, MD, Kazutaka Aonuma, MD, Akihiko Nogami, MD

From the Department of Cardiology, Faculty of Medicine, University of Tsukuba, Tsukuba, Japan.

Introduction
Left atrial and pulmonary vein macroreentrant tachycardia involves the left atrium (LA), a pulmonary vein (PV), and 2 conduction gaps from the previous lesion. Entrainment mapping is required to confirm the diagnosis, but it increases the risk of terminating the ongoing tachycardia. Furthermore, repeated activation mappings are needed to identify the precise location of the 2 conduction gaps between the LA and PV. A novel ultra-high-density mapping system had a unique feature that facilitated identifying the 2 PV-LA conduction gaps from a single acquired activation map. High-density mapping points with a small electrode surface improved the accuracy of the activation maps, and thereby enabled the delivery of an energy application at the precise location of the conducting channels.

Case report
A 72-year-old man with a history of pulmonary vein isolation and carina ablation was readmitted for recurrent atrial fibrillation. A recurrence of atrial fibrillation lasting several hours was documented after 3.5 years. Antiarrhythmic therapy with flecainide, propafenone, and pilsicainide all failed to suppress the recurrence of atrial fibrillation, and an atrial tachycardia (AT) was occasionally documented under the antiarrhythmic therapy. At the beginning of the procedure, the patient was in atrial fibrillation and was converted to sinus rhythm with direct cardioversion. Shortly after the direct cardioversion, an AT with a cycle length of 250 ms occurred spontaneously and sustained. Initially, activation mapping was performed in the right atrium using the Rhythmia system and Orion basket catheter (Boston Scientific, Cambridge, MA) with a small electrode surface. The activation mapping of the right atrium covered only 52% (131 ms) of the tachycardia cycle length and the earliest activation was found on the high and low septum. Also, the coronary sinus activation sequence exhibited a "chevron" activation pattern. Therefore, further activation mapping was performed in the LA. The window of interest (WOI) was adjusted to annotate the LA potentials. Activation mapping demonstrated a centrifugal activation pattern with the earliest LA activation at the posterior carina of the right PV (Figure 1A). At the earliest activation site, the LA and PV signals were fused. From the activation mapping, a PV-LA macroreentrant AT was considered as a differential diagnosis and the WOI of the acquired activation map was readjusted only to annotate the PV potentials inside the antrum (Figure 1B). The

KEY TEACHING POINTS
- Diagnosis of left atrial and pulmonary vein macroreentrant tachycardia utilizing 2 conduction gaps is sometime challenging. An entrainment mapping close to the exit or entrance site of the reentrant circuit may terminate the ongoing tachycardia.
- The Rhythmia system enables creation of different activation maps automatically from a preacquired map by changing the window of interest to focus on different potentials. The unique feature of this system facilitate identification of the conduction gaps between the pulmonary vein and the left atrium from the acquired single activation map.
- The ultra-high-density mapping system visualizes the precise locations of the conduction channels between the left atrium and the pulmonary vein, thus facilitating creation of a contiguous region.

KEYWORDS
Ablation; Activation map; Atrial tachycardia; Conduction gap; Rhythmia; Window of interest
(Hearth Rhythm Case Reports 2018;4:494–496)
Figure 1  A: Activation mapping of an atrial tachycardia demonstrated a centrifugal activation pattern with the earliest left atrial (LA) activation at the posterior carina of the right pulmonary vein (PV). At the earliest activation site, the LA and PV signals were fused. The window of interest (WOI) of the acquired activation map was adjusted to annotate the LA potentials. B: The automatically readjusted activation map after readjusting the WOI only to annotate the PV potential inside the antrum clearly demonstrated the entry site of the antrum at the anterior carina. LIPV = left inferior pulmonary vein; LSPV = left superior pulmonary vein; PA = posterior-anterior; RIPV = right inferior pulmonary vein; RL inf = right lateral inferior; RSPV = right superior pulmonary vein.

Figure 2  A: Local signal of the posterior carina during sinus rhythm, where the earliest atrial activation was recorded during the atrial tachycardia. Of note, the left atrial (black arrow) and pulmonary vein (black arrowhead) signals at the posterior carina were fused during sinus rhythm (first complex) and also during the extrasystoles from the right superior pulmonary vein (second complex). B: Fluoroscopic view of the successful isolation site at the posterior carina. ABL = ablation; AP = anterior-posterior; CS = coronary sinus; LAO = left anterior oblique.
automatically readjusted activation map demonstrated that the impulse entered the antrum at the anterior carina, then propagated posteriorly and exited the LA at the carina. A PV-LA macroreentrant circuit (figure-of-eight type) utilizing 2 conduction gaps (see the Supplemental Movie) was visualized from a single activation map. Instead of performing entrainment mapping close to the anterior carina to confirm the reentrant circuit, the decision was made to deliver an energy application at the anterior carina, which was a possible entrance gap to the PV. A single energy application at the anterior carina terminated the AT. After the AT termination, the ablation catheter was placed at the posterior carina where the earliest LA activation was recorded during the AT. Fused LA and PV potentials were observed during sinus rhythm and also during extrasystoles arising from the PV, suggesting that the ablation catheter was placed at the precise location of the remaining conduction channel (Figure 2). Another single energy application delivered at the posterior carina abolished the PV potentials. The reconnected left superior and left inferior PVs were also isolated and the absence of PV potentials was confirmed after a waiting period of over 30 minutes. In addition, high-rate atrial pacing was repeatedly performed under an isoproterenol (3 μg/min) infusion and the noninducibility of any atrial arrhythmias was confirmed.

**Discussion**
The conventional diagnostic approaches for PV-LA reentrant tachycardias may sometimes be difficult to apply. During entrainment pacing, identifying a paced P-wave morphology identical to that of the AT is challenging and entrainment pacing from several sites may terminate the AT. The Rhythmia system enables creation of different activation maps automatically from a preacquired map by changing the WOI to focus on different potentials. This unique technical feature enables differentiating PV-LA macroreentrant ATs from focal ATs arising after a previous ablation and identifying conduction gaps from a single map. Furthermore, high-density mapping points with a small electrode surface improve the accuracy of the activation maps, thereby enabling the delivery of energy applications at the conducting channels.

**Appendix**
**Supplementary data**
Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2018.07.001.

**References**
1. Satomi K, Bänsch D, Tilz R, Chun J, Ernst S, Antz M, Greten H, Kuck KH, Ouyang F. Left atrial and pulmonary vein macroreentrant tachycardia associated with double conduction gaps: a novel type of man-made tachycardia after circumferential pulmonary vein isolation. Heart Rhythm 2008;5:43–51.
2. Pascale P, Shah AJ, Roten L, et al. Pattern and timing of the coronary sinus activation to guide rapid diagnosis of atrial tachycardia after atrial fibrillation ablation. Circ Arrhythm Electrophysiol 2013;6:481–490.
3. Satomi K. Electrophysiological characteristics of atrial tachycardia after pulmonary vein isolation of atrial fibrillation. Circ J 2010;74:1051–1058.