Single-loop incisional atrial tachycardia encircling the entire right atrium: Where is the critical isthmus?

Masato Okada, MD, Koji Tanaka, MD, Nobuaki Tanaka, MD, Yuko Hirao, MD, Issei Yoshimoto, MD, Koichi Inoue, MD, PhD

From the Cardiovascular Center, Sakurabashi-Watanabe Hospital, Osaka, Japan.

Introduction

Identifying a critical isthmus is important when trying to ablate macroreentrant tachycardias. A critical isthmus, which typically demonstrates a slow conduction and reduced amplitude,[1,2] allows the reentrant wavefront to circulate without encountering any refractory tissue along the way. The majority of the incisional atrial tachycardias (ATs) have a macroreentrant mechanism,[3] and the entrainment pacing is an essential tool to confirm the participation of specific areas in the circuit and to identify a suitable isthmus area for ablation. However, in this case of incisional AT, entrainment with concealed fusion, which identified "isthmus" with the conventional electrophysiological maneuvers, was observed throughout the circuit. A long single-loop reentrant circuit encircling the entire right atrium produced the phenomenon, and there were no low-voltage fractionated potentials within the circuit. These findings made us reconsider the definition of "isthmus" in this kind of enclosed reentrant tachycardia.

KEY TEACHING POINTS

- Surgical incisions and anatomical barriers can create a complex long atrial tachycardia circuit without apparent low-voltage areas on its course.
- Concealed fusion with a postpacing interval equal to the tachycardia cycle length, which is typically seen in an isthmus, can be observed at multiple sites in a complex scar-mediated atrial tachycardia.
- The role of concealed entrainment as a guide for catheter ablation is limited in atrial tachycardia. Electroanatomical mapping systems help determine the complex circuit and potential ablation target.

Case report

A 61-year-old man who underwent a mitral valve surgery via the superior transseptal approach was referred for catheter ablation to treat a sustained AT (AT1) and paroxysmal atrial fibrillation. Typical flutter wave was observed on the surface electrocardiogram with a rapid ventricular rate during AT1 (138 beats per minute) (Supplementary Figure 1). Although hemodynamically stable, the patient had mild heart failure symptoms such as exertional dyspnea and cough. On admission, the chest radiograph exhibited a small pleural effusion. The plasma brain natriuretic peptide level was 214 pg/mL. The echocardiographic data revealed normal valve function but slightly impaired left ventricular function (ie, left ventricular ejection fraction of 48% with diffuse hypokinetic motion without wall thinning).

After informed consent was obtained, multipolar electrode catheters were inserted into the femoral vein and positioned in the great cardiac vein and left atrium via a transseptal approach. Subsequently, heparin was administered to achieve an activated clotting time of 250–300 seconds. Electroanatomic mapping was performed using the CARTO3 mapping system (Biosense Webster, Diamond Bar, CA). To obtain sufficient waiting time and ensure the lesion durability, we first performed the extensive encircling pulmonary vein isolation using an irrigated-tip catheter with its radiofrequency energy of 30–40 W (ThermoCool ST SF; Biosense Webster). Following the pulmonary vein isolation for the paroxysmal atrial fibrillation and identification of the sustained AT1 as a common type of atrial flutter, catheter ablation of the cavotricuspid isthmus was performed, during which the tachycardia cycle length (TCL) abruptly increased from 263 ms to 340 ms and AT1 shifted to another AT (AT2) (Figure 1B).

Because AT2 did not terminate even after completion of the linear ablation of the cavotricuspid isthmus, we subsequently performed entrainment pacing during the shifted AT (AT2). The postpacing interval (PPI) after entrainment at the cavotricuspid isthmus was 33 ms (>30 ms).

KEYWORDS Atrial tachycardia; Catheter ablation; Cardiac surgery; Critical isthmus; Entrainment
(Heart Rhythm Case Reports 2021;7:162–166)

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Conflict of Interest: Masato Okada, Koji Tanaka, Nobuaki Tanaka, Yuko Hirao, Issei Yoshimoto, and Koichi Inoue have nothing to declare for this study. **Address reprint requests and correspondence:** Dr Koichi Inoue, Cardiovascular Center, Sakurabashi-Watanabe Hospital, 2-4-32 Umeda, Kita-ku, Osaka, 530-0001, Japan. E-mail address: koichi@inoue.name.

https://doi.org/10.1016/j.hrcr.2020.12.003

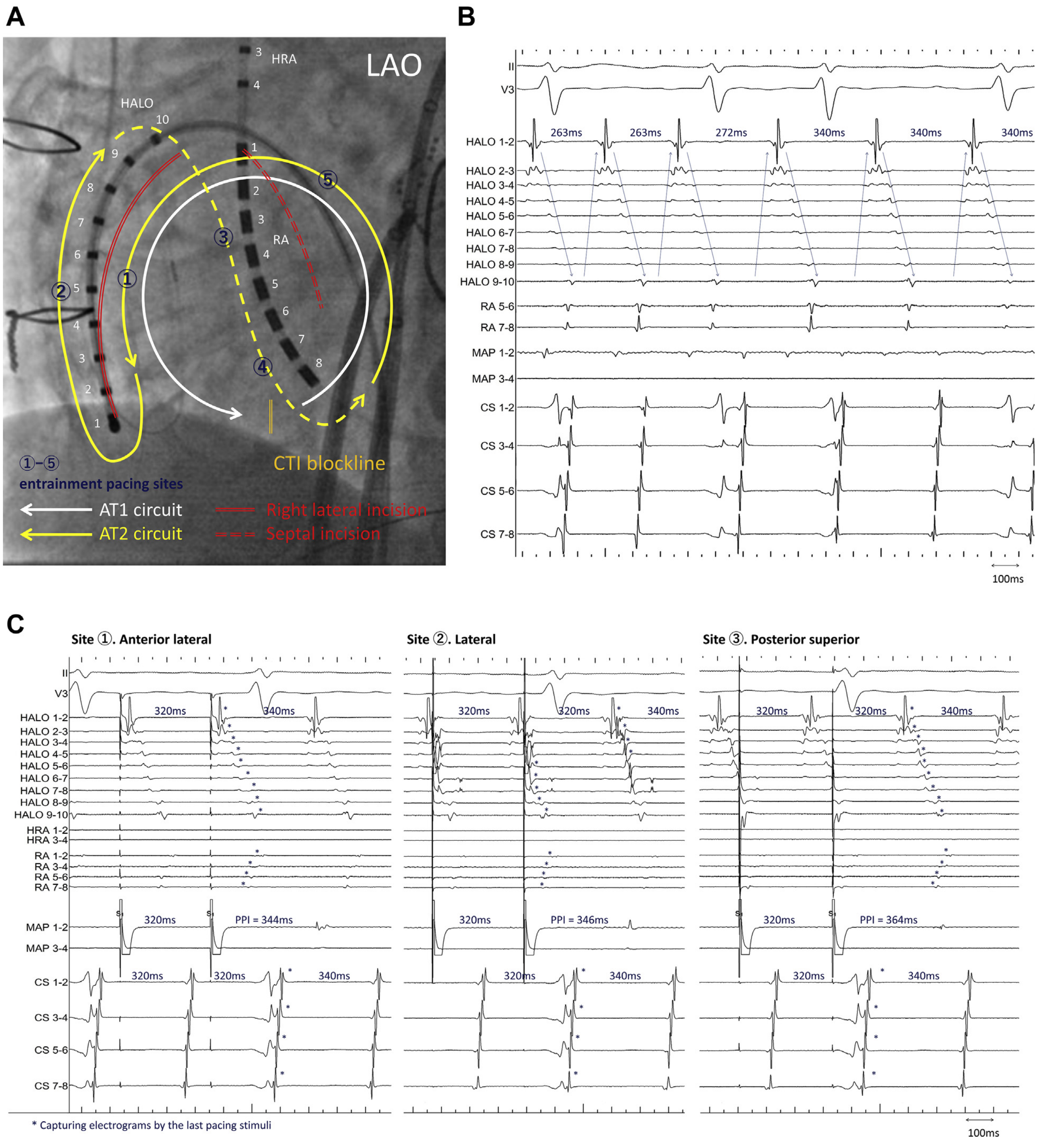

Figure 1 Fluoroscopic image and intracardiac electrograms. **A,B:** Fluoroscopic image showing the position of electrode catheters around the tricuspid valve and intracardiac electrograms during the cavotricuspid isthmus (CTI) ablation. AT1 was a common atrial flutter (A, *white arrow*), and CTI linear ablation was performed after pulmonary vein isolation, resulting in a shift from AT1 to AT2 (A, *yellow arrow*). Then, entrainment pacing from the anterior lateral (denoted by ①), lateral (②), superior posterior (③), inferior posterior (④), and anterior (⑤) regions of the right atrium revealed that the postpacing interval was almost equal to the tachycardia cycle length. In addition, the activation sequences of the catheter electrodes during pacing and the tachycardia were the same. Those findings indicated that there was an orthodromic capture of the placed catheter electrodes by the entrainment pacing. **C:** Examples of intracardiac electrograms during entrainment at sites ①, ②, and ③. II and V3 represent the surface electrocardiogram leads; HALO 1-2 to 9-10 represent the distal-to-proximal recordings of the Halo catheter positioned around the tricuspid annulus; CS 1-2 to 7-8 represent the distal-to-proximal coronary sinus recordings; and MAP 1-2 to 3-4 represent the distal-to-proximal electrograms of the ablation catheter. AT = atrial tachycardia; LAO = left anterior oblique; PPI = postpacing interval.

Conversely, concealed entrainment with a PPI almost equal to the TCL was observed at multiple sites within the right atrium (Figures 1 and 2, and Supplementary Figure 2). In addition, the stimulus-to-reference electrogram intervals were almost equal to the pacing-to-reference electrogram intervals at those sites. Activation mapping using a multielectrode mapping catheter (PentaRay; Biosense Webster) identified AT2 as a single-loop macroreentrant AT encircling

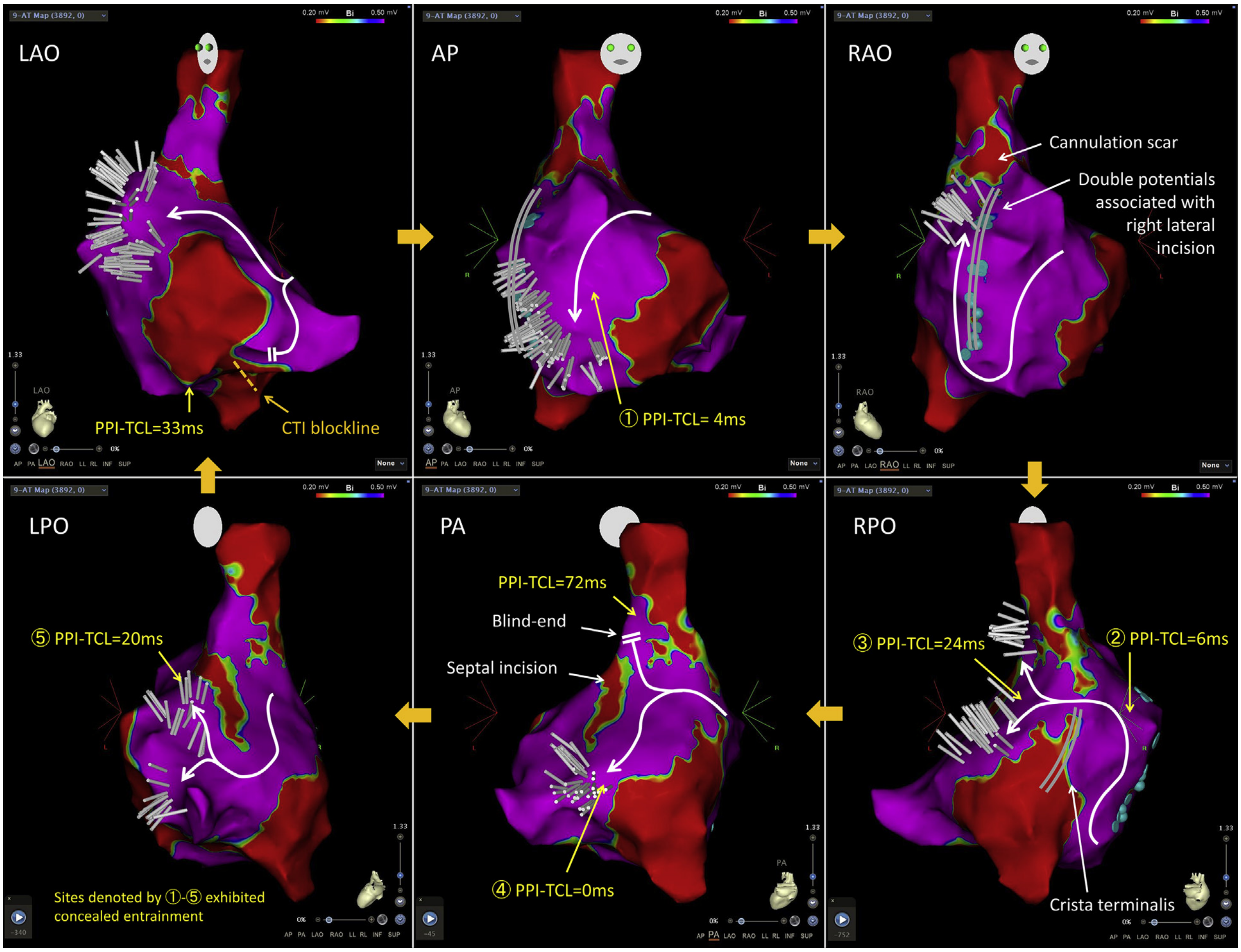

Figure 2 CARTO (Biosense Webster, Diamond Bar, CA) images describing the atrial tachycardia (AT2) circuit. Three-dimensional images of the right atrium constructed using ripple mapping during AT2 are described (see Supplementary Video). The bipolar voltage threshold to identify low-voltage areas was set to 0.2–0.5 mV. The surface color projection and points were collected aiming for a complete right atrial coverage (ie, with no areas >5 mm from a data point), and the number of points collected for this map was 3892. The white arrows indicate the direction of the wavefront propagation. The results of the entrainment at each point (*yellow arrow*) are shown. The postpacing interval (PPI) was approximately equal to the tachycardia cycle length (TCL), and entrainment with concealed fusion was observed at multiple locations within the right atrium (denoted by ①–⑤); thus, estimating the circuit using a conventional entrainment maneuver is challenging. The light blue tag points indicate double potentials associated with the right lateral incision. AP = anteroposterior; LAO = left anterior oblique; LPO = left posterior oblique; PA = posteroanterior; RAO = right anterior oblique; RPO = right posterior oblique.

the entire right atrium. Voltage mapping during AT2 identified discrete low-voltage areas possibly associated with the previous surgery. In particular, the right lateral and septal linear low-voltage areas reflected incisions created during the right atriotomy and the transseptal approach, respectively. A small scar caused by a cannulation was found proximal to the superior vena cava. The wavefront of AT2 progressed via a maze-like circuit created by conduction block lines within the incisions and anatomical barriers including the tricuspid valve, crista terminalis, superior vena cava, and inferior vena cava (Figure 2 and Supplementary Video).

Although there seemed to be multiple narrow isthmi throughout the circuit, we attempted to identify the slow conduction area using the Coherent activation mapping included with CARTO3 version 7. By increasing the conduction velocity threshold, slow conduction areas represented by thicker conduction velocity vectors were first highlighted between the right lateral incisional scar and upper portion of the inferior vena cava (Figure 3). The distance between them was 11.9 mm, which was shorter than the other alternative lines (eg, distance between the inferior portion of the lateral incision and inferior vena cava = 21.8 mm). After confirming the absence of phrenic nerve capture by pacing, we created a conduction block line by linear ablation between them, which resulted in the termination of AT2. The bipolar electrograms at the successful ablation site were fractionated but revealed a relatively short duration with a preserved amplitude (>0.5 mV) (Figure 3). During a 1-year follow-up, the patient remained arrhythmia free, and the heart failure symptoms as well as cardiac function significantly improved thereafter.

Discussion

A right atrial incision after cardiac surgery predisposes patients to complex macroreentrant ATs by creating temporal and spatial excitable gaps.[1–3] In this rare case of a single-

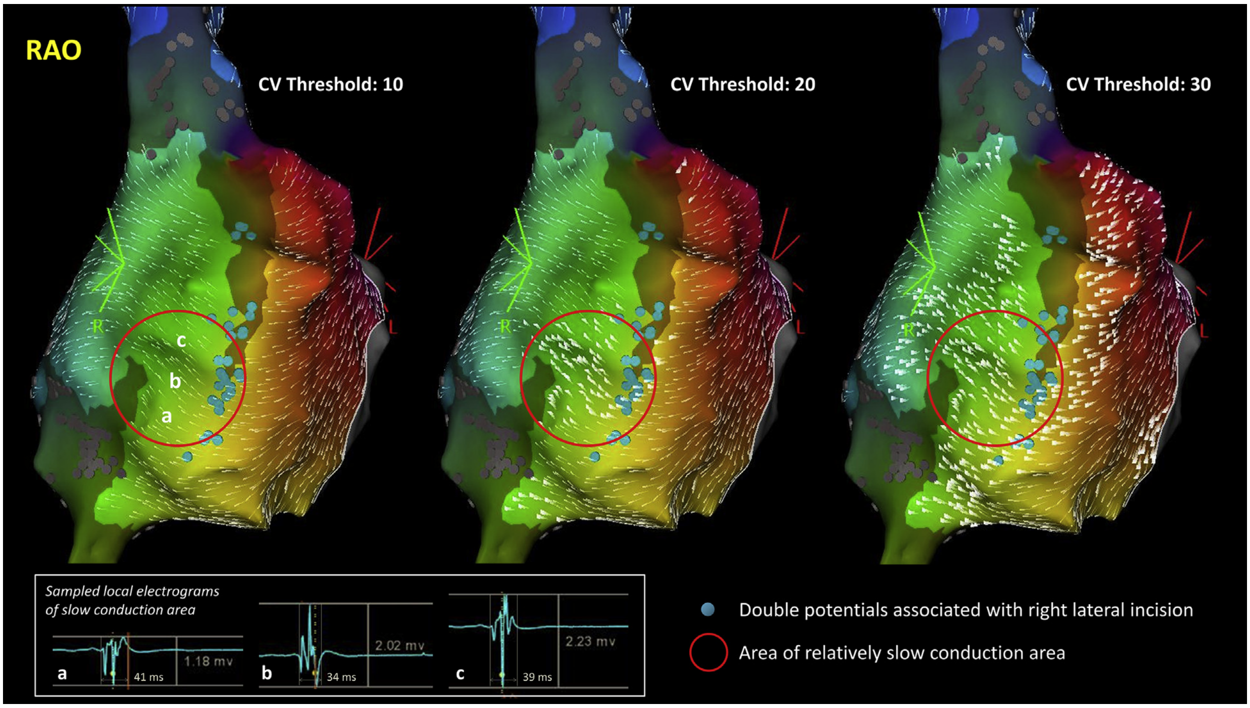

Figure 3 Method to identifying the slow conduction area. Coherent mapping with conduction velocity (CV) vectors during atrial tachycardia (AT2) are described. CV thresholds of 10, 20, and 30 mean that the slowest 10%, 20%, and 30% of the vectors are highlighted by thicker vectors, respectively. By gradually increasing the CV threshold, the areas where CV slows relative to the entire map are visualized (*red circle*). The area that is highlighted first across the circuit is a potential deceleration zone with a calculated conduction velocity of 0.37 m/s. Linear ablation across this area successfully terminated AT2. RAO = right anterior oblique.

loop incisional AT encircling the entire right atrium, the spatial excitable gap (length of the circuit that is excitable at a given time) created by incisions and anatomical obstacles may be an important contributor to the maintenance of this macroreentrant tachycardia. On the other hand, the contribution of the slow conduction to the temporal excitable gap (time during the cycle length that the circuit is excitable) was seemingly relatively small. There were no slow conduction areas (defined as $<$0.3 m/s[4]) with low voltage and prolonged fractionated potentials throughout the circuit. Similar to typical atrial flutter, the long length of the reentrant circuit might provide a sufficient spatial excitable gap within the circuit, and the wavefront deceleration would not necessarily be needed in this kind of single-loop reentrant AT.

A notable point in this case was the findings from the entrainment pacing after the cavotricuspid isthmus ablation. In the present study, concealed entrainment with a PPI matching the TCL was obtained at multiple sites within the right atrium. Although subsequent three-dimensional mapping revealed the single-loop reentrant circuit, the findings of the concealed entrainment did not provide a clue where to ablate within the circuit. In contrast to the ventricle, the atrium is predisposed to developing maze-like obstacles due to its complex anatomy, thin walled structures, and vulnerability to a hemodynamic pressure. Especially in patients who underwent catheter ablation or open heart surgery, as in this case, the multiple obstacles may limit the direction of the wavefront propagation, resulting in a reduced diagnostic accuracy of the concealed entrainment for identifying the critical isthmus.[5,6]

This limitation of the entrainment approach for identifying an isthmus highlights the importance of using electroanatomical mapping systems for a complex AT. Advancements in the 3-dimensional mapping systems and automated annotation algorithms have permitted us to create high-resolution maps with an adequate point density.[7] Of importance, we need to acknowledge that the critical areas of arrhythmogenesis mostly occur in diseased tissue where the voltage is attenuated, and handling the low voltages and complex electrograms is still a challenge when creating a precise electroanatomical map. In this case, we obtained clear boundaries between the scar and healthy myocardium using the CARTO3 mapping system, but the results might have been different using a more high-density and high-resolution mapping system (Rhythmia; Boston Scientific, Cambridge, MA). In addition, the precise recognition of the local electrograms with the Rhythmia platform would delineate a more detailed AT circuit. Conversely, though the resolution may be limited, the CARTO3 Ripple mapping algorithm, which aligns all of the recorded electrograms from each point, can display all information about the complex fractionated electrograms without mis-annotation of the local activation time. In addition, the recently developed Coherent mapping algorithm can manage these complex electrograms considering the global pattern of activation, and it enabled us to visually identify areas of conduction slowing or block.[4] In this case, the anatomically shortest site between obstacles and relatively slow conduction site overlapped with each other, and we created conduction block there, considering the potential arrhythmogenesis of the slow conduction areas and unlikeliness of occurrence of any complications. When using the 3-dimensional mapping system in complex ATs, the operators should recognize how the low-voltage and complex fractionated electrograms are handled with each platform.

Conclusion

Concealed fusion with a PPI equal to the TCL, which is typically seen in an isthmus, can be observed at multiple sites throughout the circuit in an enclosed single-loop macroreentrant AT. A recent advancement in the electroanatomical mapping systems has helped not only to delineate background obstacles and complex tachycardia circuits but also to visualize potential critical slow conduction zones in patients with macroreentrant AT. This case reminded us that a site where concealed entrainment is seen is not always consistent with an anatomically narrow site and slow conduction site in complex macroreentrant ATs. Where on the circuit you should ablate requires an integrated assessment referring to the circuit width, conduction velocity, and anatomical safety.

Acknowledgments

We would like to thank the nursing staff, clinical engineers, radiological technologists, and office administrators of Sakurabashi-Watanabe Hospital for their support in conducting this study. We also thank Mr John Martin for his linguistic assistance with the manuscript.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://10.1016/j.hrcr.2020.12.003.

References

1. Laţcu DG, Bun SS, Viera F, et al. Selection of critical isthmus in scar-related atrial tachycardia using a new automated ultrahigh resolution mapping system. Circ Arrhythm Electrophysiol 2017;10:e004510.
2. Frontera A, Takigawa M, Martin R, et al. Electrogram signature of specific activation patterns: analysis of atrial tachycardias at high-density endocardial mapping. Heart Rhythm 2018;15:28–37.
3. Zhou GB, Hu JQ, Guo XG, et al. Very long-term outcome of catheter ablation of post-incisional atrial tachycardia: role of incisional and non-incisional scar. Int J Cardiol 2016;205:72–80.
4. Vicera JJB, Lin YJ, Lee PT, et al. Identification of critical isthmus using coherent mapping in patients with scar-related atrial tachycardia. J Cardiovasc Electrophysiol 2020;31:1436–1447.
5. Nakagawa H, Shah N, Matsudaira K, et al. Characterization of reentrant circuit in macroreentrant right atrial tachycardia after surgical repair of congenital heart disease: isolated channels between scars allow "focal" ablation. Circulation 2001;103:699–709.
6. Morton JB, Sanders P, Deen V, Vohra JK, Kalman JM. Sensitivity and specificity of concealed entrainment for the identification of a critical isthmus in the atrium: relationship to rate, anatomic location and antidromic penetration. J Am Coll Cardiol 2002;39:896–906.
7. Kim YH, Chen SA, Ernst S, et al. 2019 APHRS expert consensus statement on three-dimensional mapping systems for tachycardia developed in collaboration with HRS, EHRA, and LAHRS. J Arrhythm 2020;36:215–270.