A case of an incision-related single-loop intra-atrial reentrant tachycardia showing an eccentric atrial activation sequence and widely separate potentials resembling a double-loop reentry; its mechanism and analysis

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Introduction

A supraventricular reentrant tachycardia (SVT) appearing after cardiac surgery is known to have a complicated reentrant circuit, such as a figure-8 pattern based on a double-loop reentry using both an incisional line and the cavotricuspid isthmus (CTI). In order to determine the reentrant circuit of the SVT, detailed mapping using a 3-dimensional (3-D) electroanatomical mapping system during the tachycardia is essential.[1,2]

We present an incision-related single-loop reentrant SVT, resembling a double-loop reentry,[1] which was correctly diagnosed by analyzing the special positional relationship between the multipolar electrode catheter and the incision.

Case report

A 12-lead electrocardiogram of the SVT in Figure 1A is documented from a 72-year-old woman with previous atrial septal defect repair. After informed consent was obtained, an invasive electrophysiological study and ablative procedure were performed, along with recordings around the tricuspid valve (TV) using a duodecapolar catheter (Halo; St. Jude Medical, Irvine, CA), as well as at the right atrium (RA), His bundle area, and coronary sinus (CS), under fluoroscopic guidance. The distal Halo 1-2 and proximal 19-20 electrode pairs are positioned at the 7 o'clock and 12 o'clock location around the TV in left anterior oblique view, respectively. Figure 1B illustrates intracardiac recordings during the SVT, with a cycle length of 270 ms induced by atrial stimulation. The SVT has a unique atrial activation sequence, as shown by arrows, and widely separate potentials (SPs) on the Halo 7-8 and 9-10 electrode pairs, of which the interval between the first (SP1) and second potential (SP2) was 110 ms on the Halo 9-10. The activation sequence seems to be a figure-8 pattern due to a dual-loop reentry.[1] Also, slight cycle length alternans by 10 ms was noted during the tachycardia. To determine the reentrant circuit of this tachycardia, entrainment pacing at a cycle length of 250 ms during the tachycardia was performed at multiple different atrial sites. Figure 2A-C represents the entrainment pacing outcomes from the Halo 1-2 electrode pair with multicomponent atrial potentials; the Halo 15-16, showing the turning point of the activation sequence; and the proximal CS 7-8, respectively. Differences between these postpacing intervals and the tachycardia cycle length suggest that the tachycardia is a macroreentry, including areas near the Halo 1-2 and 15-16 electrode pairs but not involving the CS 7-8 area.

Linton et al[3] proposed a sophisticated practical criterion detecting either single- or double-loop reentry by entrainment pacing at 2 different atrial sites. Bidirectional arrows in Figure 2A and C show the interval between the first atrial beats of the tachycardia on the Halo 1-2 and CS 7-8 electrode immediately after termination of entrainment pacing. It was 220 ms at the Halo 1-2 and -50 ms at the CS 7-8. The difference of these values, 270 ms (220 ms minus -50 ms), was equal to 1 tachycardia cycle length. Thus, the tachycardia was considered a single-loop reentry. The difference would be twice the tachycardia cycle length for a double-loop reentry.

Radiofrequency catheter ablation (RFA) was performed at the inferolateral free wall with a fragmented and multicomponent atrial potential (A*) near the Halo 1-2 electrode pair shown in Figure 2D (and the white dot of Figure 3A), at which pacing had the postpacing interval equal to the tachycardia cycle length (not shown in Figure 2). It led to the

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KEY TEACHING POINTS

- A double-loop reentry (DLR) characterized by a figure-8 pattern is often observed in a supraventricular reentrant tachycardia (SVT) associated with cardiac surgery. The presence of an incision created by surgery, in addition to the anatomic obstacles, can play an important role in the occurrence of the DLR using both the incision and the cavotricuspid isthmus (CTI).
- Therefore, it should be suggested that the additional incisional line can contribute greatly to occurrence and perpetuation of a common atrial flutter (AFL) dependent on the CTI. Thus, a single-loop reentry not involving the AFL is considered relatively rare.
- The findings similar to the DLR observed in our case could be determined to be based on the specific positional relationship between the multipolar catheter and the incision. Thus, such a precise analysis can reduce unnecessary energy deliveries of ablation.

cessation of the tachycardia after the disappearance of the fragmentation (Figure 2E). These findings imply the presence of the slow conduction in this area.[4,5] Continuous linear RFA lesion was extended to the inferior vena cava and additional CTI linear ablation was performed.

Discussion

Shah et al[1] described a figure-8, dual-loop, intra-atrial reentrant case with an eccentric activation sequence similar to our patient (in their Figure 2C), showing that the counterclockwise torque of a HALO catheter leading to the position astride an atriotomy line could disclose complete loop of clockwise activation on lateral wall of the RA spanning a full cycle length. Similarly, our tachycardia is considered not a focal atrial tachycardia but a macroreentrant one, because of atrial potentials on the HALO catheter almost spanning a full tachycardia cycle length. There were reports stating that the posterior functional block line in the sinus venosa region during common atrial flutter produced the dual-loop macroreentry and double potentials.[6,7] Figure 3A depicts the positional relationship among electrode catheters, the incisional line (blue dots) suggested by double potentials

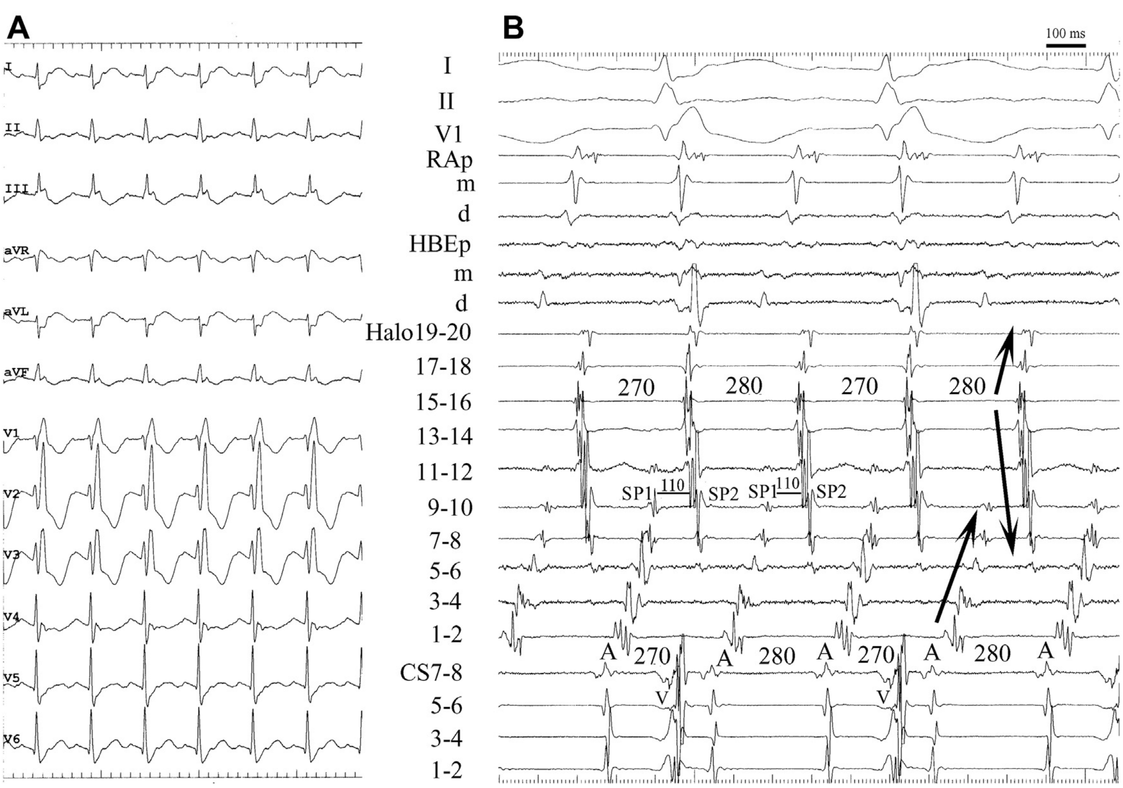

Figure 1 Surface 12-lead electrocardiogram (ECG) (**A**) and intracardiac electrograms (**B**) of the tachycardia. **A:** There are no typical saw-tooth-like waves in inferior leads. **B:** ECG leads I, II, and V1 and intracardiac electrograms from the right atrium (RA; p, m, and d; proximal, middle, and distal), the His bundle area (HBE), around the tricuspid valve (Halo; 19-20 proximal and 1-2 distal), and the coronary sinus (CS; 7-8 proximal and 1-2 distal) are shown from top to bottom at a paper speed of 100 mm/s. The tachycardia has a cycle length of about 270 ms and an eccentric atrial activation sequence from the Halo 1-2 to 19-20 electrode pairs with widely separate potentials (SPs) on the Halo 7-8 to 9-10 electrograms. Note the cycle length alternans of the tachycardia, 270 ms and 280 ms. See text for details. Number on the Halo 9-10 indicates the interval between the first portion of the SPs (SP1) and the second portion (SP2). Arrows indicate the atrial activation sequences. Note that the atrial activation sequence changes near the Halo 15-16 electrode pair. A = atrial potential; V = ventricular potential. These abbreviations, the Halo and CS electrograms arrangement, and paper speed are the same as in the next figures.

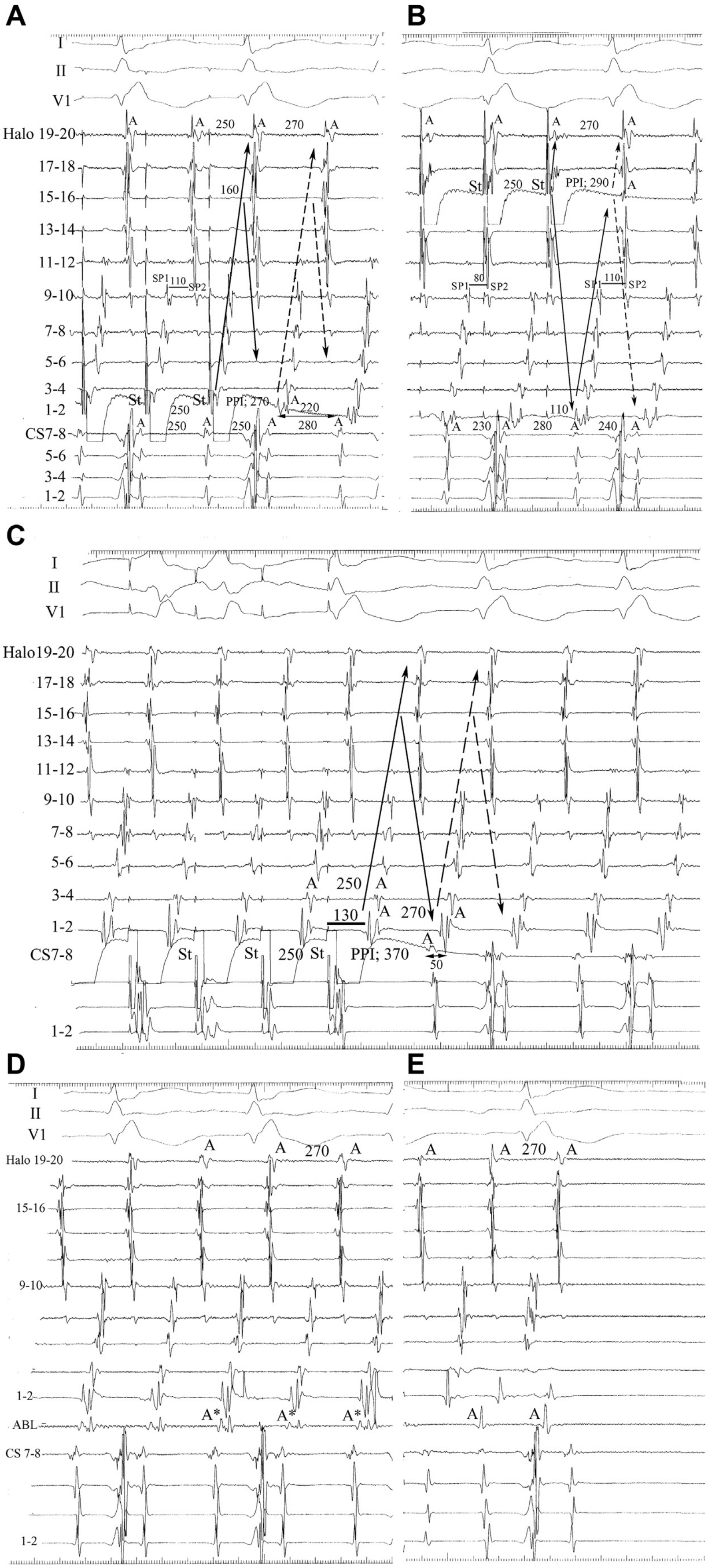

Figure 2 Outcomes of entrainment pacing at multiple atrial sites of the Halo electrode (**A** and **B**), proximal coronary sinus (**C**), and successful ablation site (**D**) and termination (**E**). **A** and **B** show the entrainment pacing with a pacing cycle length of 250 ms at the Halo 1-2 and 15-16 electrode pairs, respectively. Solid and broken arrows indicate the atrial activation sequences corresponding to the last stimulus (St) and the first beat of the tachycardia immediately after the last St, respectively. Postpacing intervals (PPIs) represent the first tachycardia cycle length immediately after the last stimulus. **A:** After an impulse stimulated at the Halo 1-2 electrode pair reaches the Halo 15-16 with a conduction time of 160 ms in a caudocranial direction, it goes down toward the Halo 1-2 in an opposite direction. Thereafter, the tachycardia resumes. Thus, the PPI is identical to the tachycardia cycle length. Note that the interval between the SP1 and the SP2 is the same value as that during the tachycardia. A figure on a bidirectional arrow indicates an interval between the first atrial beats of the tachycardia on the Halo 1-2 and the CS 7-8 electrode immediately after the last St. **B:** A pacing impulse at the Halo 15-16 can reach the Halo 1-2 with a conduction time of 110 ms in a craniocaudal direction and go back toward the Halo 15-16 in an opposite direction, followed by the resumption of the tachycardia. Thus, the PPI is 290 ms. Note that the interval between the SP1 and SP2 on the Halo 9-10 during the entrainment pacing is 80 ms, shorter than that during pacing at the Halo 1-2. Also, the oscillation of atrial cycle lengths exists only at the CS 7-8 electrodes. This indicates that the pacing impulse traveled to the CS 7-8 through other route(s) different from the tachycardia circuit. **C:** Entrainment pacing from the CS 7-8, so that the PPI is 370 ms. Therefore, the CS 7-8 site could be considered to be far from the reentrant circuit. Additionally, the interval between the stimulus artefact and the Halo 1-2 required 130 ms, much longer than that during the tachycardia. See text for details. A figure below a bidirectional arrow illustrates the same interval as that shown in panel A. **D:** Successful ablation site. **E:** Termination of the tachycardia during the first energy delivery, respectively. Note that in panel D, the distal electrode pair of the ablation catheter (ABL) has the fragmented and multicomponent atrial potentials (A*) similar to that on the Halo 1-2, and in panel E, the tachycardia terminates after the atrial potentials on the ABL are rendered single.

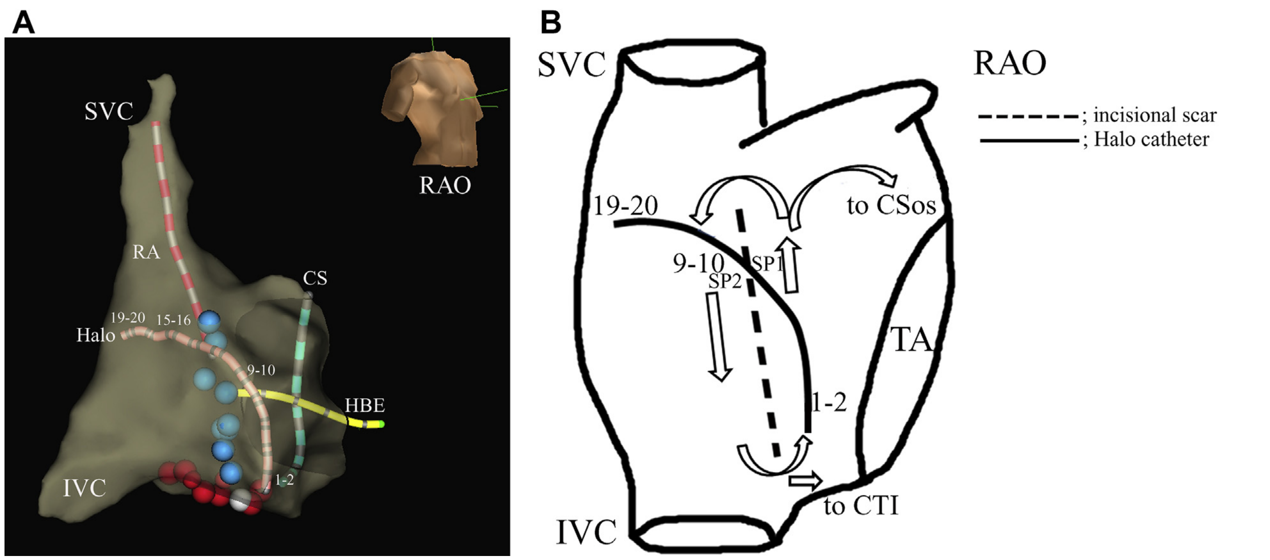

Figure 3 Positions of electrode catheters, incision, and ablations on the 3-dimensional right atrial map (**A**) and the schema of the incisional single-loop intra-atrial reentrant tachycardia (**B**). **A:** The positional relationship of electrode catheters (Halo, RA, CS, and HBE), the incisional line (*blue dots*), and ablations (*red dots*), including the first site (*white dot*) on the 3-dimensional RA electroanatomic map in right anterior oblique (RAO) view. SVC = superior vena cava; IVC = inferior vena cava; Halo = duodecapolar electrode; RA = right atrium; CS = coronary sinus; HBE = His bundle electrode. **B:** Schema of the RA in RAO view with an activation sequence of the tachycardia indicated by blank arrows, rotating around the incisional line (the interrupted line) in a counterclockwise direction. The continuous line denotes the HALO catheter. Numbers indicate the electrode pairs on the HALO catheter in panel B as well as panel A. CSos = ostium of coronary sinus; SP1 and 2 = the first and second portion of separate atrial potentials on the Halo 9-10 electrode pair, respectively; TA = tricuspid annulus; CTI = cavotricuspid isthmus. See text for details.

observed during sinus rhythm, and RFA sites (red dots), including the first and successful one (the white dot) on the 3-D RA electroanatomical map created using an Ensite NavX system (St. Jude Medical, Minnetonka, MN). Our SVT was a single-loop reentry associated with the incision, and recording sites of the SPs were apparently different from the sinus venosa region. Moreover, as shown in Figure 2A and B, although the duration between the SPs during entrainment pacing at the Halo 1-2 was the same value as that during the tachycardia, that at the Halo 15-16 was shorter, namely 110 ms vs 80 ms. It implies that a stimulation impulse at the Halo 15-16 reached the SP2 earlier than that at the Halo 1-2. Therefore, it is probable that each of the SP1 and SP2 potentials during pacing at the Halo 1-2 (or the tachycardia) should be considered to originate in order from separate depolarizations of both sides of atrial tissues, which, isolated by the incision, are produced not by collision of double wavefronts[6,7] but by the identical activation wavefront. Judging from these findings, we hypothesized the geneses of the unique atrial activation sequence and wide SPs with the schema of Figure 3B, as follows: The electrodes from the Halo 1-2 to 5-6 existed within the common isthmus between the incision and the TV, the Halo 7-8 and 9-10 with SPs astride the incision, and the remaining posteriorly to the incision. Namely, an impulse starting at the Halo 1-2 could register apparent atrial potentials on the electrograms from the Halo 1-2 to 9-10 (SP1) electrode pairs going up along the incisional line in a caudocranial direction, because of being positioned within the isthmus. Thereafter, the activation wavefront turned over the upper end of the incision near the Halo 15-16, subsequently propagating down toward the Halo 1-2, so that the impulse yielded apparent atrial potentials on the Halo 15-16 to 9-10 (SP2) and/or 7-8 localized posteriorly against the incision. Because of such a specific positional relationship between the HALO catheter and the incision, our single-loop incision-related intra-atrial macroreentry was considered to masquerade as being a double-loop pattern. Despite deviating from the argument, it may be important to speculate about the conduction routes between the ostium of the CS (CSos) and the tachycardia circuit. During the tachycardia, an atrial potential of the CS 7-8 was slightly earlier than that of the Halo 1-2 (Figure 1B), and entrainment pacing from the CS 7-8 required the long conduction time to reach the Halo 1-2 (130 ms; Figure 2C). Judging from these findings, we hypothesized on the basis of a single-loop reentry, as follows: During the tachycardia, an atrial potential of the CSos was passively activated by an impulse along not the CTI but the posterior right atrial wall (Figure 3B), which could allow the atrial potential of the CSos to slightly precede that of the Halo 1-2. To the contrary, during the entrainment pacing from the CS 7-8, the activation wavefront might pass slowly through the CTI in the clockwise direction toward the Halo 1-2, around which the slow conduction existed. Furthermore, the mechanism of the cycle length alternans during the tachycardia may be very difficult to be clarified. In Figure 1B, SP1-to-SP2 intervals and atrial electrograms on the CS 7-8 to the following Halo 1-2 were fixed. Thus, it is possible that the decremental conduction in the area between the lower turnaround of the circuit and the CSos plays a role; the long pause allows shortening of the conduction, which then served as an extrastimulus leading to the prolongation of the next cycle length.

To our knowledge, it has rarely been pointed out that the reason why an incisional reentrant atrial tachycardia had the unique activation sequence and the wide SPs could be explained only by the special positional relationship between the multipolar electrode catheter and the incision.

Conclusion

Because a HALO catheter is usually fixed in the posterior position to the TV under biplane fluoroscopy, care is not always taken of the position of the incision line during the procedure. Therefore, it may be important that an operator move the HALO catheter to the position astride an atriotomy line using the counterclockwise-torque technique.[1]

Acknowledgments

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