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Case Report

An Alternative Approach for Radiofrequency Catheter Ablation for Intra-atrial Reentrant Tachycardia Associated with Open-Heart Surgery

Sumito Narita MD[*1,*2], Takeshi Tsuchiya MD[*1], Keiichi Ashikaga MD[*1], Koji Miyamoto MD[*1], Izumi Taniguchi MD[*1], Shin-ichi Ando MD[*2]

[*1]EP Expert Doctors - Team Tsuchiya
[*2]Division of Cardiology, Saiseikai Futsukaichi Hospital

We present case reports of 2 patients with scar-related intra-atrial reentrant tachycardia (IART) associated with previous open-heart surgeries, in which standard ablation strategies failed to eliminate atrial tachycardia (AT). The strategies targeted a narrow conducting channel between the right atrial scars or between the scar and inferior vena cava. In these patients, an alternative approach to transect another narrow conducting pathway between the scar and crista terminalis (CT), which was revealed by a noncontact mapping system, successfully terminated and eliminated the IART. Both the cases were free of recurrent AT at the 24- and 25-month follow up visits, respectively. Transection of the corridor between the CT and the incision scar appears to be an effective technique for eliminating scar-related IART and can be considered as a second-line procedure for radiofrequency catheter ablation to eliminate IART.
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Key words: noncontact mapping, intra-atrial reentrant tachycardia, ablation

Introduction

Postoperative intra-atrial reentrant tachycardia (IART) is a common late complication of open-heart surgery[1–8)] and is sometimes fatal because of hemodynamic deterioration and thromboembolism. Some "standard" approaches of radiofrequency catheter ablation (RFCA) have been used, which target a narrow conducting pathway between dense scars within a low voltage zone or one between the scar and the anatomical obstacle. However, these strategies fail to eliminate the atrial tachycardia (AT) in some patients.

We present case reports of 2 patients with postoperative IART, in whom the standard approach failed. An alternative approach, which was performed by navigation using a noncontact mapping system (NCM), was used to transect another narrow conducting pathway between the incisional scar and the crista terminalis (CT) in these patients, which successfully eliminated the AT. Nine cases are presented as a control, in which the standard approach successfully eliminated the postoperative IART with right atriotomy.

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Address for correspondence: Takeshi Tsuchiya, EP Expert Doctors-Team Tsuchiya, Koto 3-14-28, Kumamoto, Japan. TEL: +81-96-368-0403 FAX: +81-96-368-0414 E-mail: tsuchiya@s1.kcn-tv.ne.jp

Case Report

Electrophysiologic Study and Ablation Procedures

Written informed consent was obtained from each patient before the study commenced. Electrophysiologic studies were performed in the fasting state. RFCA was performed while patients were under conscious sedation with intravenous administration of hydroxyzine pamoate (25–50 mg).

According to standard prodedures, a quadripolar electrode catheter was placed at the His bundle region (SJM, Minnetonka, MN, USA), and two 20-pole electrode catheters were placed within the coronary sinus (CS) and along the tricuspid annulus, respectively (SJM). The multielectrode array catheter (MEA) of the NCM (SJM) was introduced into the right atrium from the right femoral vein, and the tip of the MEA was placed at the superior vena cava. Virtual activation mapping was performed in the right atrium (RA) during IART and sinus rhythm. Details of the NCM were described elsewhere.[9,10)]

Throughout the study, the activated clotting time (ACT) was monitored every 30 minutes; if it went below 200 seconds, an adequate amount of heparin was injected to maintain it between 200 and 300 seconds. The local conduction block line was determined to be where the conduction block was shown in the virtual activation map with subsequent activation coming from other directions. The block line was confirmed by the morphology of the virtual unipolar electrogram (VUE), which exhibited an RS-R or RS-RS pattern with a time interval between the first and second components.[9,10)] During sinus rhythm and CS pacing, the virtual activation map depicted CT as a longitudinal obstacle at the lateral RA. At the visually detected CT, it was further confirmed by contact bipolar and VUE which exhibit double potential.

After induction of IART, RA activation and central obstacle corresponding to a possible scar were revealed by virtual activation map and were further confirmed by the morphology of VUE and contact bipolar mapping, which showed double potentials or electrical silence. In the suspected arrhythmogenic channels, entrainment pacing was performed to validate the reentrant circuit if possible.

In each case, an 8-mm tip catheter (Fantasista, Japan Lifeline, Co., Ltd; Blazer II, Boston Scientific, Co., Ltd) was used for ablation. Radiofrequency energy was delivered in a temperature-controlled fashion, upper limits being 50 °C and 50 W. The procedural endpoints were IART termination and absence of re-inducibility and confirmation of regional block line creation examined by NCM.

Case 1

A 58-year-old man developed antiarrhythmic-drug refractory narrow QRS tachycardia 14 years after the closure of atrial septal defect (ASD) (**Figure 1a**). Common atrial flutter was initially induced via rapid RA pacing, which was terminated and eliminated by the line creation at the cavotricuspid isthmus (CTI). After that, IART was induced by rapid RA pacing; rotating activation around the possible RA scar at the lateral RA in a clockwise direction was revealed by the virtual activation map of the NCM. At the possible RA scar, a line of double potentials was recorded by the VUE, and a line of double potentials or electrical silence was observed by the contact bipolar electrograms. It was noted that the activation went up between the possible RA scar and CT, which might be another narrow conducting pathway in addition to the well-known channel between the scar and inferior vena cava (IVC) (**Figure 2a**).

Linear ablation from the bottom of the RA scar to the IVC was attempted many times, but failed to terminate the IART because the RF energy was reduced substantially in response to the increase in temperature at the ablation catheter tip. Then, another narrow conducting pathway between the possible RA scar and CT was transected, and the IART was terminated after completion of the line creation (**Figure 2b**). After that, the completeness of the line was confirmed by the virtual activation of the NCM during RA pacing, in which RA activation coming from the lower part of the line was blocked and subsequent activation arrived from the opposite direction towards the line. No complications resulted, and the patient has been free of AT recurrence over a follow-up period of 24 months.

Case 2

A 53-year-old female suffered from narrow QRS tachycardia 35 years after the closure of ASD (**Figure 1b**). At first, a slow-fast form of atrioventricular nodal reentrant tachycardia was induced by RA pacing, and the slow pathway was eliminated via standard slow pathway ablation. Burst pacing from the CS subsequently induced common atrial flutter, which was also eliminated by the block line creation at the CTI. Finally, an IART that was activated in a manner similar to that in case 1 was observed by the NCM (**Figure 3a**). The linear ablation from the bottom of the possible incision line to the IVC failed to terminate the AT because of the presence of intractable persistent conduction in the lower part of the incision line. Thus, an alternative ablation strategy (i.e., transverse ablation connecting the

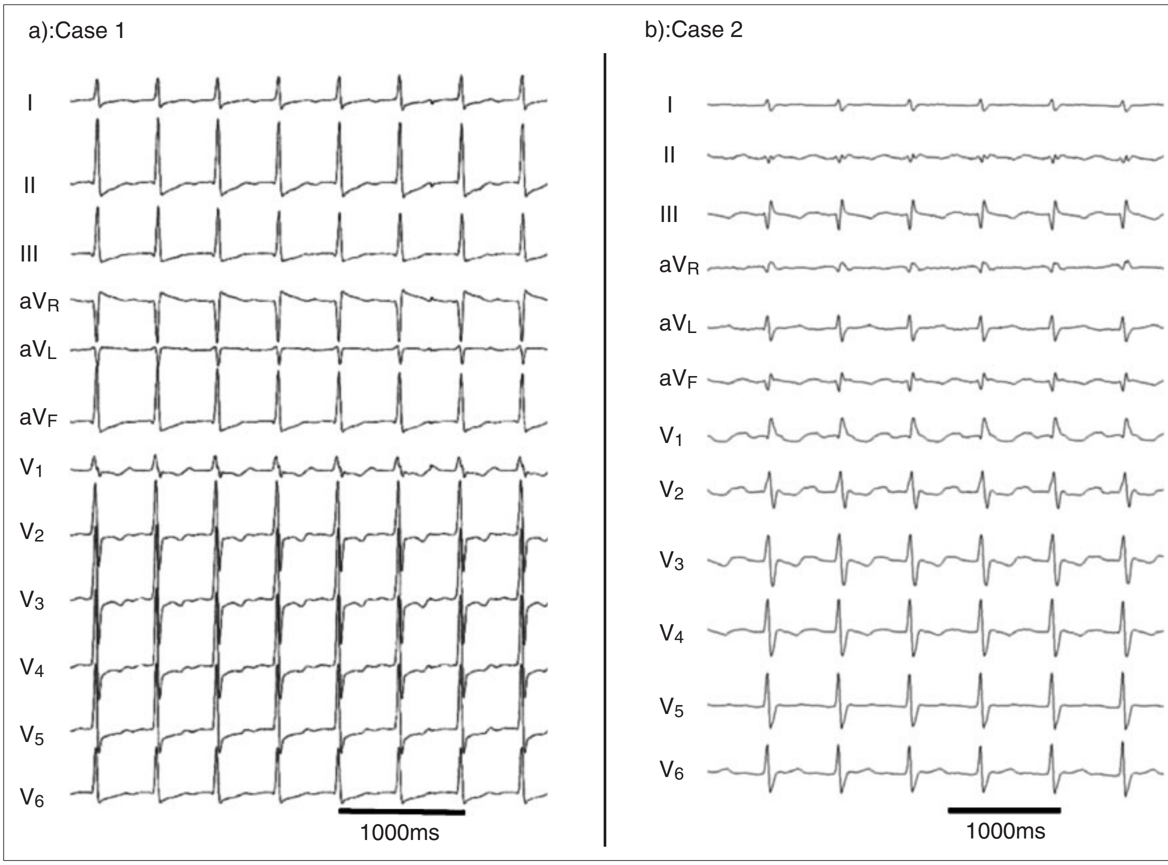

Figure 1
a) Twelve-lead EKG of the intra-atrial reentrant tachycardia (IART) in case 1. **b)** Twelve-lead EKG of the IART in case 2.

incisional line to the CT) was employed, which successfully eliminated the IART (**Figure 3b**). No complication resulted, and the patient has been free of IART recurrence over a follow-up period of 25 months.

Comparison between those in whom the standard strategy of ablation was successful and those in whom the alternative strategy was successful

In an attempt to clarify the clinical features of patients in whom the standard ablation approach was unsuccessful and in the patient in whom the alternative approach was needed to eliminate the IART, some clinical, anatomical, and electrical parameters were examined in comparison with 9 patients in whom postoperative IART with right atriotomy was eliminated by the standard approach (control group). In the former 2 patients, age, IART cycle length, the distance from the bottom of the scar to IVC, number of delivered RF pulses, and delivered RF energy were 58/53 years, 308/304 ms, 19/25 mm, 18/13 times, and 29297/20350 J respectively. In the control group, the parameters were 55 ± 16 years, 270 ± 41 ms, 22 ± 7 mm, 12 ± 5 times, 12189 ± 8507 J, respectively (mean $\pm$ S.D.). Furthermore, in all the patients, the morphology of the contact bipolar recordings at the bottom of the incisional line was biphasic or polyphasic. The amplitude and the width of the electrogram at the site was 0.254/0.220 mV and 76/84 ms in the former 2 patients and 0.264 ± 0.167 mV and 109 ± 20 ms in the control group, respectively (**Table**).

Discussion

Virtual activation map of the NCM visualized full-cycle length activation of the postoperative IART, which rotated around the possible incision line located at the lateral RA in all patients in the presented cases. There appear to be 2 potential narrow conducting pathways. The first is a well-known area—a "channel" of IART between the bottom of the possible incision line and IVC. The second is a relatively long linear region—a "corridor" between the possible incisional line and CT. The "channel" is considered to be the standard target

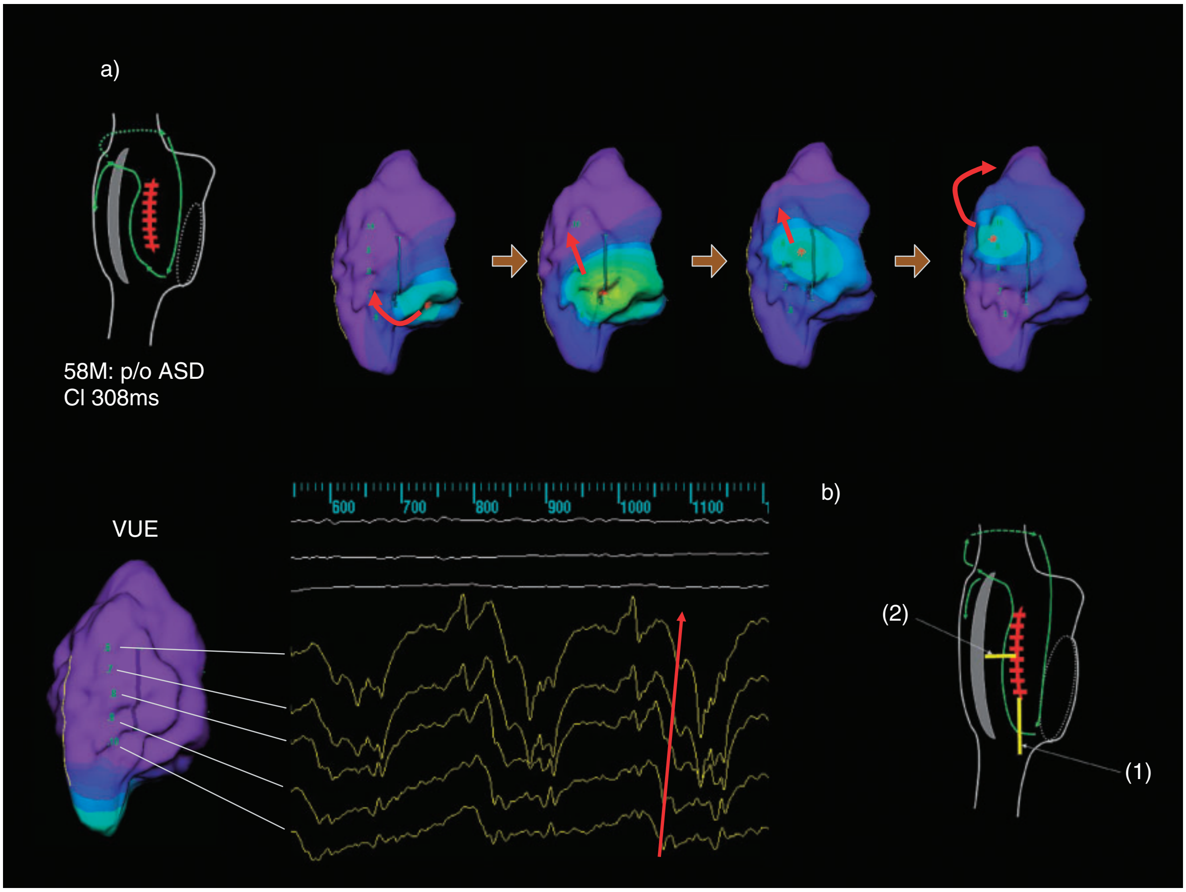

Figure 2
a) Dynamic wavefront map of IART in case 1, which developed 14 years after surgical closure of atrial septal defect. The wavefront passed through the "corridor" of the lateral right atrium, which is composed of the incision line and the crista terminalis. It wrapped around the posterior superior vena cava and went down the anterior portion of the tricuspid valve. A virtual unipolar electrogram (VUE) along with the corridor showed a sequential R wave followed by an S wave. Possible incisional lines are shown as thick black lines in the right atrial image, the location of which was confirmed by the fact that double potentials with a baseline or electrical silence were recorded by contact bipolar recording at the site. **b)** Ablation strategy for case 1. Initially, conventional block line formation was attempted from the incisional line to the inferior vena cava, which was unsuccessful in terminating the IART. Subsequently transverse lesion was lined between the incision line to crista terminalis, which successfully terminated the IART.

for the incision-related IART patients that underwent open-heart surgery with RA free wall incision.[1–6)] The "corridor" is considered to be an alternative ablation target in patients in whom the standard ablation approach is unsuccessful.

There are 2 possible reasons why NCM can, but the electroanatomical mapping cannot, elucidate the activation going up at the "corridor," although, in some cases, the corridor can be transected to eliminate IART under navigation with the electroanatomical mapping system.[11)] The first reason may be differences in resolution as a activation mapping between the 2 mapping systems, i.e., the virtual activation map of the NCM is constructed with a VUE of >3300 points on the endocardial surface, which is derived from an inverse solution to Laplace's equation using a boundary element method. In contrast, an activation map from an electroanatomical mapping system is usually constructed with contact bipolar electrograms at 100–200 points on the endocardial surface.

The second reason may be the difference in the recording method between the 2 mapping systems. The NCM is constructed with VUE, whereas electroanatomical mapping is constructed with contact bipolar electrograms. A unipolar electrogram represents both local and distant electrical activities, despite lower electrogram amplitude with longer distances. This indicates that the unipolar electrogram may be hampered by large, remote electrical activity of depolarization or repolarization with respect to the distance, but the intrinsic deflection

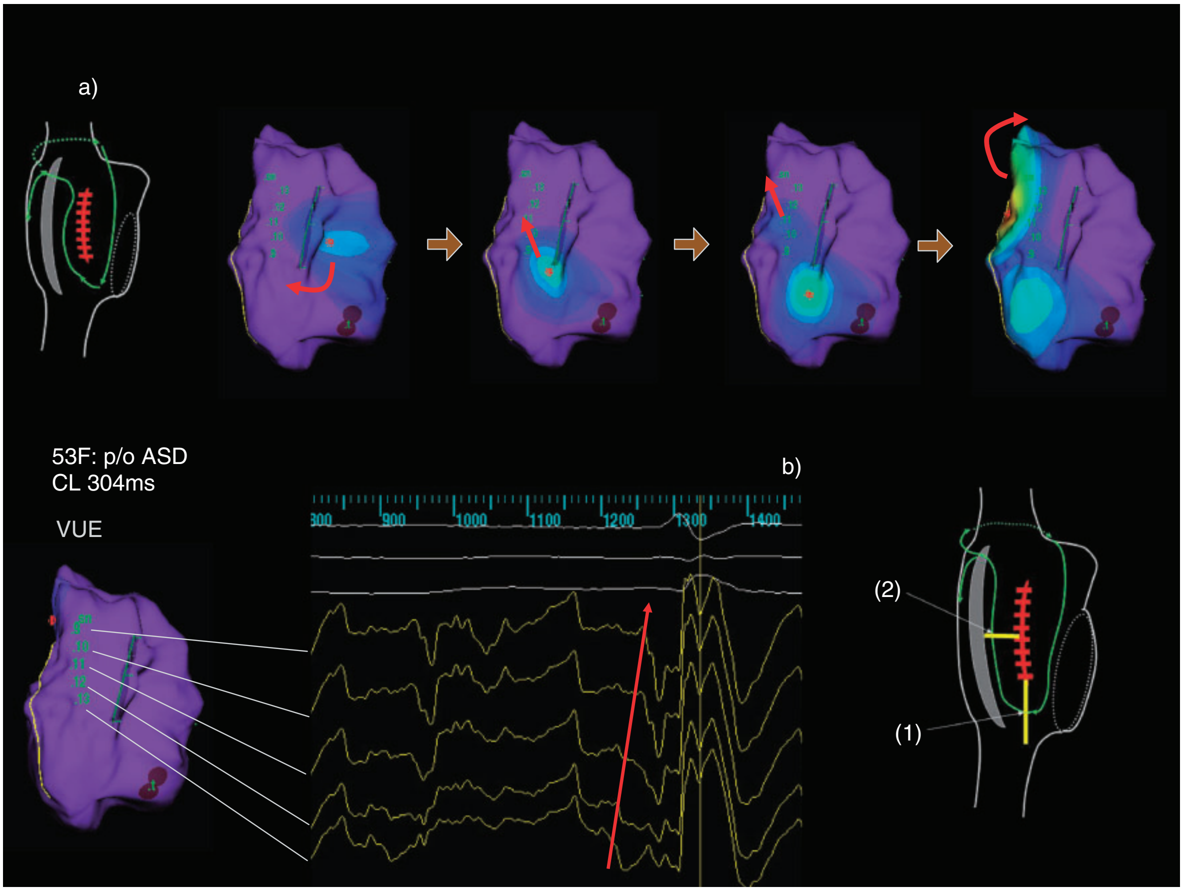

Figure 3
a) Dynamic wavefront map of IART in case 2, which developed 35 years after surgical closure of atrial septal defect. The wavefront passed through the 'corridor' of the lateral right atrium, which is composed of incision line and crista terminalis. It wrapped around the posterior superior vena cava and went down the anterior portion of tricuspid valve. A virtual unipolar electrogram (VUE) along with the corridor showed a sequential R wave followed by an S wave. Possible incisional lines are shown as thick black lines in the right atrial image, the location of which was confirmed by the fact that double potentials with a baseline or electrical silence were recorded by contact bipolar recording at the site. **b)** Ablation strategy of case 2. Initially, conventional block line formation was attempted from the incisional line to the inferior vena cava, which unsuccessfully terminated the IART. Subsequently, transverse ablation connecting the incision line to the crista terminalis was performed, which successfully terminated the IART.

is still a reliable marker of local activation and the interpretation is usually easy, even at sites with a slow conduction zone or a local conduction block. In the present study, caution was taken to avoid the effects of remote electrical activities, i.e., the MEA catheter was placed at a site closest to the possible RA incision, and the virtual activation map was performed during a long R-R interval or just after intravenous injection of adenosine tri-phosphate injection to prolong the R-R interval. In addition, those who had a large RA were excluded from the study because local activation at the endocardial site distant from the center of the MEAs >4.0 cm are not accurate.[12,13)]

Bipolar recording uses the electrode reference closest to the exploring electrode; thus, distant electrical activity is cancelled by subtracting the far-field electrical activity, in which the difference between the electrical activities at the local electrode and reference electrode is recorded. However, this subtraction sometimes makes the interpretation of electrograms difficult, especially fractionated, fragmented, or continuous electrograms, which are sometimes recorded at the abnormal conducting sites with slow conduction, local conduction block, pivot, and anisotropy. In the present cases being studied, local conduction block occurred during the IART at both the incision site and at the CT. At these sites, complex bipolar electrograms with double, triple, or even fractionated morphology were usually recorded, which makes the determination of local activation time difficult. However, discrete intrinsic

Table Clinical demographic data of the cases

case	age	sex	OHD	CL (ms)	Inc-IVC (mm)	RF Pulse (n)	RF Energy (J)	Electrograms at the Inc-IVC		
								morphology	amplitude (mV)	width (ms)
Patients who needed the alternative approach										
1	58	M	ASD	308	19	18	29297	biphasic	0.254	76
2	53	F	ASD	304	25	13	20350	biphasic	0.220	84
Patients with successful results by the standard approach										
3	48	F	ASD	257	24	22	22799	polyohasic	0.090	69
4	75	M	ASD	237	16	9	11650	biphasic	0.530	130
5	38	M	AVSD	236	34	12	9239	polyphasic	0.054	116
6	71	M	MVP	260	30	17	13158	polyphasic	0.320	152
7	41	F	ASD	240	20	5	4857	polyphasic	0.190	80
8	66	M	ASD	369	14	9	8652	biphasic	0.260	125
9	76	F	AS	252	9	7	5243	N.D.	0.581	N.D.
10	27	F	AVSD	259	28	13	2599	polyphasic	0.120	122
11	56	M	myxoma	244	21	6	6236	polyphasic	0.280	133
mean	55			270	22	12	12189		0.264	109
S.D.	16			41	7	5	8507		0.167	29

N.D.: Not discernible

OHD: organic heart disease, ASD: atrial septal defect, AVSD: atrioventricular septal defect, MVP: mitral valve prolapse, AS: aortic stenosis, CL: cycle length, Inc-IVC: distance from incisional line to inferior vena cava (IVC), RF Pulse: number of radiofrequency ablative pulses delivered to make block lines from the incision line to the IVC, RF Energy: total radiofrequency energy delivered to make block lines from the incision line to the IVC, Morphology: the morphology of local contact bipolar electrogram recorded at the bottom of the incision line in each case.

deflection is usually demonstrated by unipolar recording, even in such abnormal conducting tissue, which makes the determination of local activation time easy, making a clear demonstration of the local conduction block at the site.

In the present study, it is unclear why the standard ablation approach failed to eliminate the IART in the 2 patients presented. No outstanding differences in length from the bottom of the incision line to the IVC or in the electrical parameters of the morphology, amplitude, and width of the bipolar electrogram at the regions between the presented cases and controls were observed, which suggests that the anatomical and electrical characteristics at the site were similar between the 2 groups. In one patient (case 1), RF energy delivered to that site was restricted to a substantially lower level because of an increase in the temperature rise at the tip of the ablation catheter, which may have been due to a low local blood flow rate and thus less cooling effect at the tip of the ablation catheter during ablation. The use of cooled-tip ablation catheter might solve this problem; however, this type of ablation catheter has not been approved yet in Japan. In the other patient, repeat delivery of sufficient RF energy failed to create a block line at the site, and the presence of an intractable persistent conduction in the lower part of the incision line was still evident after several applications of RF energy. This may have been due to a thickened RA wall at the region, but earlier it was difficult to predict this from the electrical and anatomical parameters.

The old version of NCM used for ablation of IART in activation and dynamic substrate maps, constructed with VUE, had some limitations, because full-cycle length activation of the IART is sometimes difficult to elucidate. Furthermore, there was a concern about the reliability of the dynamic substrate map when compared with voltage map constructed with contact bipolar electrograms. However, with the recent version (6.0 J) of EnSite, ablative technology based on analysis of the voltage map constructed with contact bipolar electrograms is possible. Therefore, we believe that the NCM can be used in all patients with IART, which can provide detailed full-cycle length activation of the AT and substrate information from a combination of virtual unipolar and contact bipolar recordings, even when we can use the irrigation catheter in Japan.

Conclusion

The use of NCM for analysis and navigation during post surgical IART ablation was feasible and effective. Transverse ablation via corridor between the CT and the incision scar is a possible alternative when the standard approach is unsuccessful.

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