Original Article

Efficacy of Electroanatomical Mapping for Radiofrequency Ablation of Right-sided Accessory Pathways

Tiejun Li MD, Yasushi Miyauchi MD, Yoshinori Kobayashi MD, Yu-ki Iwasaki MD, Tsutomu Horie MD, Hiroshi Taniguchi MD, Yasuhiro Hirasawa MD, Mitsunori Maruyama MD, Akira Ueno MD, Junko Abe MD, Takao Katoh MD, Teruo Takano MD

The First Department of Internal Medicine, Nippon Medical School, Tokyo, Japan

Introduction: Due to the difficulty in performing detailed mapping around the tricuspid annulus and the high occurrence of mechanical trauma during the procedure, the outcome of right-sided accessory pathway (AP) ablation still has a relatively high primary failure and recurrence rate.

Methods and Results: Six patients with right free-wall APs underwent electroanatomical mapping. The AP had retrograde unidirectional conduction in 3 patients, anterograde unidirectional conduction in 1 patient, and bidirectional conduction in 2 patients. The right atrial (RA) activation map was constructed during right ventricular (RV) pacing (n = 5), and the RV activation map was constructed during RA pacing (n = 3). During mapping, the AP conduction was interrupted by catheter mechanical trauma in 3 patients. The first RF application successfully eliminated the AP conduction within 2 seconds in 3 patients with concealed pathways. In the remaining 3 patients, rescue RF energy was delivered at the tagged bump site on the map. The mean procedure time was 214 ± 77 minutes, and mean fluoroscopy time 63 ± 23 minutes. No recurrence occurred during 12 ± 3.2 months of follow-up in any of the patients.

Conclusions: With the guidance of an electroanatomical mapping system, right-sided accessory pathways can be satisfactorily eliminated without later recurrence.
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Key words: Wolff-Parkinson-White syndrome, Mechanical trauma

Introduction

Radiofrequency catheter ablation (RFCA) is the first line treatment in symptomatic patients with atrioventricular accessory pathways (APs) with more than 90% probability of success. However, RFCA of right-sided APs continues to have higher primary failure and recurrence rates.[1–5] Some of the reasons include unstable catheter contact around the tricuspid annulus, inadequate reference structures like the coronary sinus for left-sided AP mapping, and high occurrence rates of mechanical trauma during manipulation.[6–12] Electroanatomical mapping can generate a real-time three-dimensional geometric map of the selected chambers containing both anatomical and electrophysiological information, facilitating

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Address for correspondence: Yasushi Miyauchi MD, The First Department of Internal Medicine, Nippon Medical School, 1-1-5 Sendagi, Bunkyo-ku, Tokyo 113-0022, Japan. Phone: +81-3-3822-2131 (Ext. 6736) Fax: +81-3-5685-0987 E-mail: miyauchi@nms.ac.jp

mapping and orientation of the catheter.[13] Thus, in this study, we decided to evaluate the efficacy of an electroanatomical mapping system (CARTO, Biosense Webster, Diamond Bar, CA, USA) for RF ablation of right-sided accessory pathways.

Methods

1) Study patients

Six consecutive patients (3 men, 3 women; age 38 ± 26, range 15–68 years) were included in the study. Three patients had manifested preexcitation on the surface ECG, and 3 had concealed APs. They all had symptomatic tachycardias manifested on the Holter electrocardiogram. One patient with concealed AP also had episodes of atrial flutter and atrial fibrillation, and 1 had mild hypertension. One patient with manifest preexcitation had 2 previous ablation procedures that were followed by recurrence 3 days and 14 days later. No cardiac anomalies were found.

These patients underwent an electrophysiological study and subsequent catheter ablation. All procedures in the present study were approved by the Ethical Committee of Nippon Medical School, and written informed consent was obtained from every patient.

2) Electrophysiologic study

The electrophysiologic study and RFCA were performed in a fasting and mildly sedated state with intravenous administration of midazolam. All antiarrhythmic agents were discontinued for at least 5 half-lives before the study. Three 6 Fr quadripolar catheters were introduced percutaneously from the femoral veins and positioned at the right atrial appendage (RAA), the His bundle region and the right ventricular apex (RVA). A 6 or 7 Fr decapolar catheter was introduced from the right internal jugular vein and advanced into the coronary sinus (CS). Intracardiac electrograms from these catheters along with the 12-lead body surface electrocardiogram were recorded with EP-Workmate (EPMed Systems, NJ, USA). Bipolar intracardiac electrograms were filtered at a band-pass of 30–500 Hz. Programmed electrical stimulation was performed with a cardiac stimulator (EP-3 Clinical Stimulator, EPMed Systems, NJ, USA) using a 2 ms rectangular impulse at twice the late diastolic pacing threshold. The stimulation protocol included incremental pacing and single and double extrastimuli at two different basic cycle lengths (600 and 400 ms) from the RAA and RVA. Right-sided APs were diagnosed using conventional criteria.[14]

3) Electroanatomical mapping

Electroanatomical mapping was performed after the diagnosis of a right-sided pathway was made. The method was similar to that published previously.[13] Briefly, a reference patch (Refstar, Biosense-Webster, Diamond Bar, CA, USA) was taped to the back of the patient and the reference catheter for timing was placed in the RV for anterograde mapping of the AP and in the CS for retrograde mapping. A 7F deflectable 4-mm tip catheter (Navistar, Biosense-Webster, Diamond Bar, CA, USA) was introduced to perform the activation mapping during pacing, an RA activation map was constructed during RV pacing, and an RV activation map during RA pacing at 500 ms cycle lengths, respectively. A long sheath (SR2, St. Jude Medical, Daig Division, Minnetonka, MN, USA) was used to assist mapping when necessary. The earliest atrial or ventricular activation site displayed on the electroanatomical map was considered to be the pathway insertion site.

4) RF catheter ablation

RF energy was applied at the earliest activation site as demonstrated on the electroanatomical map. RF current was delivered between the distal 4-mm tip electrode and an adhesive skin electrode on the patient's back. An RF generator with a closed-loop temperature system incorporated (Atakr, Medtronic Inc, USA) was used, and the target temperature was set at 60 °C. If the AP conduction was interrupted by catheter-induced mechanical trauma, then the mechanical block site was immediately marked on the map and radiofrequency rescue and insurance pulses were applied there and to the surrounding sites. The endpoint was the freedom of recurrence of the conduction over the AP at least 30 minutes after the ablation under the infusion of isoproterenol at a rate of 0.01–0.02 μg/kg/min. The results were compared with those in 10 age-matched patients (39 ± 17 years) who underwent RFCA of right-sided accessory pathways without using electroanatomical mapping.

5) Post-ablation follow up

All patients underwent routine outpatient follow up at cardiology clinic or by referring physicians. Antiarrhythmic agents were withheld after the ablation procedure. The occurrence of atrioventricular reciprocating tachycardia (AVRT) or the reappearance of delta waves on the 12 lead electrocardiogram was considered a recurrence.

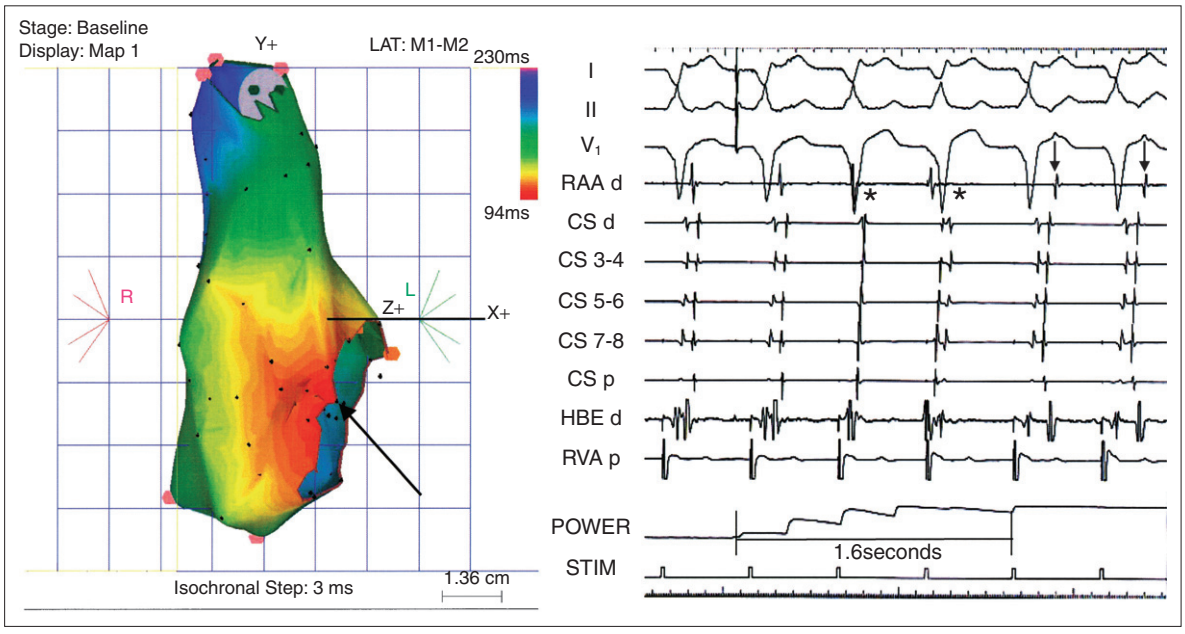

Figure 1 The left panel shows a right atrial activation map in the anterior-posterior view during right ventricular (RV) pacing in a patient with a right-sided concealed accessory pathway.
The earliest atrial activation site (arrow) is located at the right lateral tricuspid annulus. The right panel shows the surface and intracardiac electrograms during the first RF application at the earliest activation site during RV pacing, which successfully eliminated the accessory pathway conduction in 1.6 seconds. Note the change in the atrial activation sequence to the posterior AV node pattern (arrow) following 2 premature beats indicated by asterisks. RAA = right atrial appendage; CS = coronary sinus; HBE = His bundle electrogram; RVA = right ventricular apex.

Results

1) Baseline EPS

In all patients a right free-wall AP was detected. The AP had retrograde unidirectional conduction in 3 patients, anterograde unidirectional conduction in 1 patient, and bidirectional conduction in 2 patients. Orthodromic AVRT at a cycle length of 380 ± 20 ms was reproducibly induced by either RV or atrial programmed stimulation.

2) Electroanatomical mapping

An average of 78 ± 25 points were sampled to construct the geometry and activation map, consuming 53 ± 15 minutes. An RA activation map during RV pacing (**Figure 1**) was constructed in 5 patients, including 2 with bidirectional and 3 with concealed APs. The atrial insertion site of the AP was located at the right free wall in all patients. An activation map of the RV during RA pacing was constructed in 3 patients with manifest APs. The earliest ventricular activation site was located on the lateral tricuspid annulus. In the patient with 2 prior RFCA procedures with subsequent recurrence, an oblique course of the AP was identified (**Figure 2**). In that patient, there was an 18 mm distance between the earliest atrial and ventricular activation sites around the tricuspid annulus. In that patient, we also performed microcatheter-assisted right coronary artery mapping, which showed a discordance between the earliest atrial and ventricular activation sites of approximately 16 mm (**Figure 3**). There was a 4-mm distance between the atrial and ventricular earliest sites in the other patient with a bidirectional AP.

3) Radiofrequency catheter ablation

In 3 patients, the first radiofrequency energy application was applied at the earliest atrial activation site determined by the atrial activation map during RV pacing. In such patients, the first RF application successfully eliminated the AP conduction within 2 seconds (1.2 ± 0.6 s) from the onset of the delivery (**Figure 1**). The number of RF applications delivered until achievement of successful ablation (1.0 ± 0) was significantly smaller than that in patients with no electroanatomical mapping (7 ± 6, $p < 0.01$). In the remaining 3 patients, the accessory pathway conduction was interrupted by catheter manipulation during mapping. Since we carefully monitored the activation sequence, we were able to mark the site where the "bump" occurred. In such a situation, the catheter was

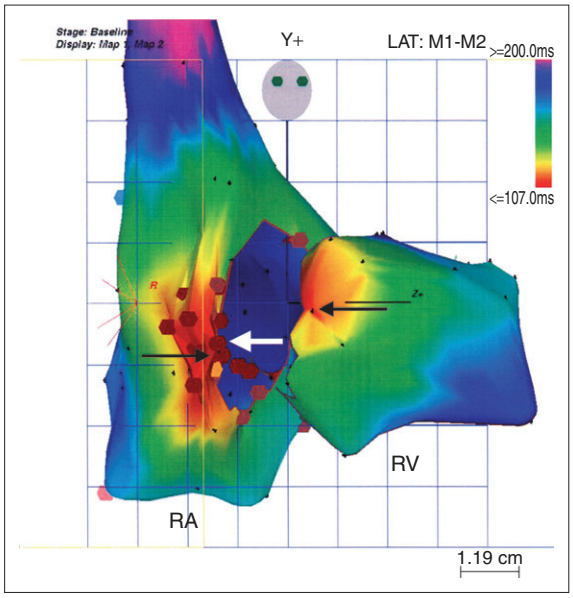

Figure 2 A right atrial (RA) activation map during right ventricular (RV) pacing in the right anterior oblique view, superimposed on the RV activation map during sinus rhythm in a patient with 2 prior RFCA procedures with subsequent recurrence.
The black arrows indicate the earliest activation sites. During sinus rhythm, the location of the catheter, which was at the earliest atrial activation site during RV pacing, was changed to the site tagged yellow due to a different atrial geometry. There is an 18 mm distance between the earliest atrial and ventricular activated sites, which implies that the AP has an oblique course. In this patient catheter induced mechanical trauma occurred when the catheter was located at the site indicated by the white arrow. The "rescue" RF application was delivered at that site, and then additional RF applications were delivered at 7 sites surrounding the first site as indicated by the brown dots.

navigated back to the site where the bump occurred to deliver RF energy. In addition to an RF delivery at the site where the "bump" occurred, additional RF energy applications were applied at 4–9 sites (6.6 ± 2.0 sites) surrounding the "bump" site (**Figure 2**). The mean procedure time (214 ± 77 minutes) and the mean fluoroscopy time (63 ± 23 minutes) were shorter than those in patients with no electromapping (281 ± 90 min, $p = 0.07$, 74 ± 33 min, $p = 0.48$, respectively), however, the differences were not statistically significant.

No significant procedure-related complications developed and no recurrences were observed after 12 ± 3.2 months of follow-up in these 6 patients, whereas 2 of 10 patients with no electromapping, both with catheter induced mechanical bump, recurred 3 days and 1 month after the procedure.

Discussion

A series of studies had been performed that elucidated the reasons for primary failure and recurrence in patients undergoing catheter ablation of APs. The results demonstrated a strong influence by the location of the AP, and a higher probability of primary failure and recurrence was associated with right-sided APs.[6–10] These location-dependent differences can be explained by the effectiveness of accurate mapping and adequate tissue heating. Unlike mapping of left-sided APs, where an accessible venous structure like the coronary sinus around the mitral annulus is available, mapping of right-sided APs usually can only be guided by the local eletrogram and motion of the catheter tip under fluoroscopy. The catheter instability during right atrial manipulation and the resulting difficulty in the localization and obtaining stable tissue heating may also lead to ablation failure and recurrence.

The CARTO system is a magnetic nonfluoroscopic mapping and navigation system. It can reconstruct the anatomy of selected chambers as well as electrophysiological information, and navigate the catheter to a specific site without fluoroscopic monitoring.[13] In the present study, all 6 patients were successfully ablated with the guidance of electroanatomical mapping. After the activation maps were constructed, further intensive mapping around the earliest activation site identified the optimal ablation site. In all 3 patients in whom activation maps could be made without interruption by mechanical trauma during catheter manipulation, the first RF application successfully terminated the AP within 2 seconds. Even when mechanical trauma occurred, we were able to accomplish permanent elimination of the conduction by applying the RF energy at the site where the "bump" occurred. Such rescue RF applications with conventional methods, without using electroanatomical mapping, are associated with higher recurrence rates up to 33.3%.[11]

Septal and right-sided accessory pathways are generally located in subendocardial positions and are especially susceptible to mechanical trauma by electrode catheters.[15] Catheter-induced mechanical trauma to the AP can lead to the disappearance, change in the preexcitation pattern or the noninducibility of the tachycardia. Pharmacological agents have generally been unable to revive the traumatized function.[11] In 24% of patients, persistent trauma-induced conduction block led to discontinuation of the ablation procedure.[12] Although the immediate application of RF current can be given at sites of mechanical block, the recurrence rate has been

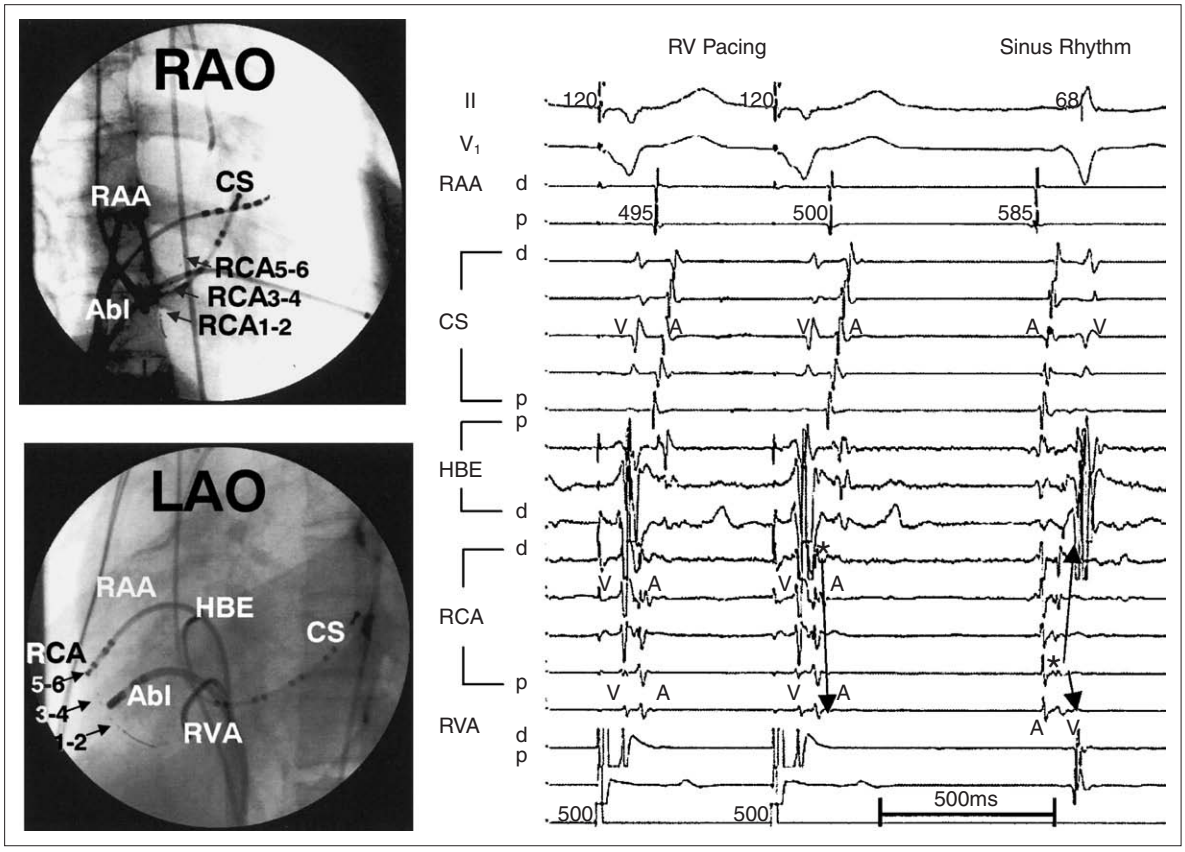

Figure 3 The left panels show the radiographs of the catheter locations including a 2.3-Fr hexapolar microcatheter with 2-8-2 mm spacing introduced into the right coronary artery (RCA) in the same patient as in Figure 2.
The right panel shows the activation sequence in the RCA which exhibits the earliest atrial (A) activation during RV pacing on the distal electrodes and the earliest ventricular (V) activation during sinus rhythm on the proximal electrodes, confirming the oblique course of the AP. RAA = right atrial appendage, RVA = right ventricular apex, HBE = His bundle, CS = coronary sinus, ABL = ablation catheter, Pathfinder = microelectrode mapping catheter.

higher in patients with mechanical trauma than in those without.[11,12] The major cause of the recurrence may be that the rescue radiofrequency ablation applications have only been delivered to the presumed bump site, which is not always the "real" bump site. The real site cannot be precisely reapproached under fluoroscopy.

Although great caution was taken during the placement of the electrode catheters in every patient during the electrophysiological study and radiofrequency ablation procedure, in 3 patients (50%) with manifest APs, catheter induced mechanical trauma to the APs occurred during endocardial mapping, implying that the insertion site of the AP was located under the endocardium near to the annulus. After the bump occurred, the bump site was immediately tagged on the electroanatomical map before the catheter was moved. By monitoring the real-time catheter tip movement within the heart, the catheter was accurately navigated back to the tagged bump site without waiting for the recovery of the AP function, and rescue ablation was carried out. Further, insurance RF applications were delivered at 4–7 surrounding sites. No recurrence was documented after 12 months of follow-up in those patients. We believe that the ability to accurately return to the bump site under electroanatomical system guidance, rather than fluoroscopy, is related to a successful outcome.

The discordance of the atrial and ventricular insertion of the accessory pathway may also lead to ablation failure. Otomo et al. reported that reversing the direction of paced ventricular and atrial wavefronts can reveal the oblique course of accessory AV pathways and improve the localization for the catheter ablation.[16] In our study, we directly compared the earliest atrial and ventricular activation sites through constructing atrial and ventricular activation maps concomitantly, and found an oblique course in 2 patients with manifest APs including 1

patient with 2 prior ablation procedures with subsequent recurrence. During RV pacing, the APs in these 2 patients were successfully ablated on the RA side. Because this anatomical variance in the APs might be one of the major factors affecting the primary failure, electroanatomical mapping of both chambers is helpful for distinctly showing the oblique course of the AP, and might especially be helpful in refractory patients.

Conclusion

Electroanatomical mapping facilitated the mapping and ablation of right-sided accessory pathways. Detailed mapping around the presumed insertion site of the accessory pathway was performed to guarantee a successful primary ablation. The capability to perform proper and precise navigation may have lowered the recurrence rate when a bump occurred during the procedure. Electroanatomical mapping might be a suitable modality for right-sided accessory pathway ablation.

Study Limitations

First, the study included a small number of patients. A randomized and prospective study including a larger number of patients may be necessary to confirm our conclusions. The incidence of mechanical trauma to the accessory pathways in the present study was more common than that in the previous reports.[11,12] That may be due to stronger contact of the mapping catheter to the accessory pathway when we used a long sheath (SR2) to assist mapping.

Acknowledements

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