Catheter ablation of para-Hisian atrioventricular accessory pathways (APs) remains challenging because of their proximity to the normal atrioventricular conduction system that may be inadvertently damaged by ablation. In a few cases, para-Hisian AP ablation may fail because of limited energy delivery at these sites or other unclear reasons when energy delivery is optimal. The inferior vena cava approach (IVC-A), the noncoronary cusp approach (NCC-A), and the superior vena cava approach (SVC-A) have been reported. However, when should para-Hisian APs be mapped and ablated by the IVC-A, NCC-A, or SVC-A is not well established.

Methods and Results—This study included 55 consecutive patients (mean age, 53±11 years, 36 males) with para-Hisian APs. On the basis of the approach resulting in successful ablation, patients were divided into IVC-A, NCC-A, and SVC-A groups. The clinical characteristics, surface ECG, intracardiac electrogram findings, and response to ablation were analyzed. Para-Hisian APs were eliminated by IVC-A in 48 of the 55 (87%) patients. The rates of para-Hisian APs requiring NCC-A (4/55 patients, 7%) and SVC-A (3/55 patients, 6%) were relatively low. During mapping at the para-Hisian region, the local ventricular and atrial potentials were well fused during retrograde AP conduction in 45 of the 48 patients in IVC-A group, 0 of the 4 patients in NCC-A group, and 1 of the 3 patients in SVC-A group, respectively. There was no significant difference in the preexcitation characteristics among the 3 groups.

Conclusion—Most para-Hisian APs can be safely and effectively ablated by IVC-A, and ablation in the NCC is not an initial or a preferred approach. The degree of local ventriculoatrial fusion in the para-Hisian region during retrograde AP conduction can differentiate or predict the successful ablation site. (Circ Arrhythm Electrophysiol. 2017;10:e004882. DOI: 10.1161/CIRCEP.116.004882.)

Key Words: catheter ablation • electrocardiography • tachycardia, supraventricular • vena cava, inferior • vena cava, superior

Catheter ablation of para-Hisian atrioventricular accessory pathways (APs) remains challenging because of their proximity to the normal atrioventricular conduction system that may be inadvertently damaged by ablation. In a few cases, para-Hisian AP ablation may fail because of limited energy delivery at these sites or other unclear reasons when energy delivery is optimal. The inferior vena cava approach (IVC-A) via a femoral vein has been a dominant approach for ablation of para-Hisian APs, and a few cases of successful para-Hisian AP ablation by the noncoronary cusp approach (NCC-A) or the superior vena cava approach (SVC-A) have been reported. However, when should para-Hisian APs be mapped and ablated by the NCC-A or SVC-A remains unclear. In this study, we report a case series of para-Hisian APs that were successfully ablated by IVC-A, NCC-A, and SVC-A and analyze the mapping and ablation characteristics and results with these approaches. The strategies for mapping and successfully ablated para-Hisian AP are discussed.
WHAT IS KNOWN

- Catheter ablation of para-Hisian accessory pathways has been challenging because of the neighboring conduction tissue.
- Some different approaches, including the inferior vena cava approach, the noncoronary cusp approach, or the superior vena cava approach, have been reported.

WHAT THE STUDY ADDS

- Most of the para-Hisian accessory pathways can be safely and effectively ablated by inferior vena cava approach, and ablation in the noncoronary cusp is not an initial or a preferred approach.
- The degree of ventriculoatrial fusion in the para-Hisian region during retrograde accessory pathway conduction can differentiate or predict successful ablation by inferior vena cava approach, noncoronary cusp approach, or superior vena cava approach in most para-Hisian accessory pathway patients.

Electrophysiology

Electrocardiographic leads I, aVF, and V1 using a multichannel recording system at a paper speed of 100 to 200 mm/s (EP MedSystems, West Berlin, NJ). The bipolar signals were filtered at 30 to 500 Hz.

A para-Hisian AP was defined when a discernible HB potential was recorded (either the largest recordable HB electrogram or an HB potential of >0.1 mV) at the site of earliest atrial activation during retrograde AP conduction or after ablation of a manifest AP with disappearance of ventricular preexcitation.

Mapping and Ablation

The presence of a retrograde AP was proven by late ventricular extrastimulus delivery during tachycardia (at the time of HB refractoriness) and para-Hisian pacing. The earliest activation region in the right atrium was initially mapped during tachycardia or retrograde AP conduction during ventricular pacing using a 4-mm-tip ablation catheter placed via a femoral vein (the IVC-A), and the Swartz long sheath was used in almost all patients with para-Hisian APs for increased catheter stability. If the earliest retrograde activation site in the right atrium or right ventricle (the ablation catheter was shaped to a reverse curve in the right ventricular outflow tract and pulled down to the subtricuspid annulus) was located near the HB area, the initial ablation was attempted by IVC-A in most patients, except 9 patients whose initial ablation was in the NCC. When the tachycardia did not terminate during right atrial radiofrequency ablation, or if the retrograde or antegrade AP conduction could only be temporally blocked, or junctional rhythm occurred frequently and A-H interval prolonged during ablation, mapping and ablation by the NCC-A was attempted. Aortic angiography was performed in most patients before catheter ablation to determine the location of the coronary arteries and to delineate the anatomy of the coronary cusp. If ablation by IVC-A and NCC-A failed to eliminate the retrograde and antegrade AP conduction, mapping and ablation by SVC-A was attempted via the right internal jugular vein or subclavian vein. Radiofrequency application at the para-Hisian site was initiated at 10 to 15 W and titrated up to 20 to 40 W (depending on the anatomic location, the response of AP and atrioventricular nodal conduction, and the appearance of junctional rhythm) for a maximum temperature of 55°C using a 4-mm nonirrigated ablation catheter. The end points of ablation were loss of preexcitation and absence of previously inducible orthodromic reentrant tachycardia. After ablation, if ventriculoatrial conduction was still present, para-Hisian pacing was used to exclude retrograde conduction over an AP.

Statistical Analysis

Values are summarized by mean±SD. The maximum amplitude of the HB potential at the ablation site and on the HB catheter was compared by paired t test. A P value of <0.05 was considered statistically significant. SPSS software version 17.0 (SPSS, Inc, Chicago, Illinois) was used for statistical analysis.

Results

All 55 patients presenting with para-Hisian APs underwent successful ablation. Successful ablation sites were located in the para-Hisian region by IVC-A in 48 patients (87%), including 9 patients with unsuccessful initial ablation in the NCC. Among the 4 patients (7%) with successful ablation in the NCC, 1 had an initial attempt ablation in the NCC instead of IVC-A, in which the decision to target the NCC was based on previous experience of V-A not well fused in the para-Hisian region during retrograde AP conduction suggestive of an NCC site, and 3 patients (6%) underwent successful ablation by SVC-A after failed ablation by IVC-A and NCC-A.

Comparison of Electrophysiological Characteristics Between Patients With Successful Ablation of Para-Hisian AP via Different Approaches

In the IVC-A group, focal ventricular and atrial potentials were well fused in 45 patients (45/48) in the para-Hisian region during retrograde AP conduction (Figure 1). The maximum amplitude of the HB potential at the ablation site and on the HB catheter was 0.12±0.06 mv and 0.41±0.12 mv (P=0.00), respectively; and the mean A/V ratio at these ablation sites was 0.44±0.20. In 9 consecutive patients, initial ablation of the AP in the NCC was performed, although the atrial activation in the right HB region preceded the atrial activation in the NCC by 12±4 ms. Ablation failed in all these 9 patients, including in 1 patient whose AP could be blocked transiently during ablation. All 9 patients were eventually successfully ablated by IVC-A with nonirrigated energy ablation.

In the NCC-A group, the ventricular and atrial potentials were not well fused in the para-Hisian region during retrograde AP conduction in all 4 cases (Figure 2). During mapping in the NCC, the earliest atrial activation during AP conduction was located in the NCC adjacent to the right coronary cusp. The earliest atrial activation in the NCC preceded the atrial activation in the para-Hisian region by 0 to 14 ms. Ablation in the NCC eliminated the AP in the 4 patients (Figure 3), and a tiny HB potential was recorded at the ablation site in only 1 of the 4 patients (Figure 2, case 2). The mean A/V ratio at these ablation sites was 1.07±0.51. In 1 patient, irrigated energy (35 W, infusion rate 20 mL/min) was delivered in the NCC and eliminated the AP after ablation with a nonirrigated catheter resulted in only transient AP conduction block. AP conduction could be blocked temporarily at the right para-Hisian region in 2 patients during ablation.

In the SVC-A group, the ventricular and atrial potentials were well fused in the para-Hisian region in 1 case, and an isoelectric interval was recorded in 2 cases during tachycardia (Figure 4). All 3 patients were initially mapped by IVC-A and NCC-A, of which 2 cases had good mapping results in the para-Hisian region with clear His potential, and 1 case had no good mapping result either in the para-Hisian region or in NCC. Ablation of the AP failed in all the 3 patients by both IVC-A and NCC-A, but eventually succeeded by SVC-A with nonirrigated energy.
Preexcitation was present in 22 of the 55 (40%) patients, including 19 patients in the IVC-A group, 1 patient in the NCC-A group, and 2 patients in the SVC-A group. In all these patients, the 12-lead ECG during sinus rhythm showed a positive delta wave in lead I, II, and aVF, a positive or isoelectric delta wave in lead III, and an isoelectric/negative delta wave in lead V1, which was consistent with an anteroseptal AP. There was no significant difference in the preexcitation characteristics on surface ECG among the patients in the IVC-A, NCC-A, and SVC-A groups (Figure 5).

Follow-Up
There were no complications including complete atrioventricular block during the perioperative period. No antiarrhythmic drugs were administered after ablation. All the patients were followed up for 8 months to 7 years (3.2±2.1 years) by telephone or clinic service. Recurrence was observed in 2 patients with ablation by IVC-A, one of whom underwent successful reablation by IVC-A and the other refused reablation procedure because of only one episode of recurrence. No recurrence occurred in patients who achieved successful ablation by NCC-A or SVC-A.

Discussion

Major Findings
In this large case series of para-Hisian AP ablation, the mapping and ablation results using different approaches were reported and analyzed. Most of the para-Hisian APs could be safely and effectively ablated by IVC-A. The incidence of para-Hisian APs requiring ablation from the NCC was relatively low (4/55 patients, 7%) and initial ablation of para-Hisian APs in the NCC failed in 9 consecutive patients, so ablation from the NCC was not a preferred approach. Ventriculoatrial fusion during retrograde AP conduction in the para-Hisian region could differentiate or predict successful ablation by IVC-A, NCC-A, or SVC-A in most patients with para-Hisian APs. Ablation from the SVC-A should be considered when mapping does not show earlier activation time or when ablation fails by IVC-A and NCC-A.

Electrocardiographic Features
In this study, preexcitation on surface ECG was present in 40% of patients. The preexcitation characteristics among the patients in the IVC-A, NCC-A, and SVC-A groups do not differ significantly from each other, although the small number of patients presenting with preexcitation in the NCC-A group (1 patient) and in SVC-A group (2 patients) limits comparison of preexcitation characteristics.
Electrophysiological Mapping and Ablation Characteristics

In this study, AP conduction was successfully ablated with lower energy (most patients at 10–30 W) at the right para-Hisian region and without collateral atrioventricular conduction damage in 48 patients. During the electrophysiological study, the ventricular and atrial potentials were fused during retrograde AP conduction in 45 of the 48 IVC-A group patients. The amplitude of the His potential on the ablation catheter at successful sites was lower than that recorded by the HB catheter, and the amplitude of atrial potential was smaller than the ventricular potential, indicating a safer ablation target nearer the ventricle.

In 4 patients from the NCC-A group, the ventricular and atrial potentials were not well fused, and eventually the para-Hisian AP was eliminated in the NCC with higher radiofrequency energy or irrigated energy. The earliest atrial activation in the NCC preceded that at the HB region by 0 to 14 ms, and a tiny HB potential was recorded at the site of the earliest near-field atrial activation in 1 of the 4 patients (Figure 2, case 2).

Fluoroscopic images showed that the successful ablation sites in the NCC adjacent to the right coronary cusp were slightly superior to those at the para-Hisian region (Figure 3). This might explain why the para-Hisian APs could be eliminated in the NCC with higher ablation energy in some patients. In this study, the para-Hisian APs were successfully ablated by SVC-A in 3 cases after failure by both IVC-A and NCC-A.

Different Techniques and Approaches for Ablating Para-Hisian APs

Several techniques and approaches for ablating para-Hisian APs have been reported, which aim to increase success rate and reduce potential complications. The techniques and approaches include low-energy radiofrequency ablation, long sheath support, cryomapping and cryoablation, ablation via IVC-A (above or below the tricuspid annulus), NCC-A, and SVC-A. Cryo energy is frequently suggested as a potential alternative to radiofrequency ablation because it has a lower incidence of complications, but its recurrence rate is notably higher than that with radiofrequency energy.8–11 The use of the SVC-A for ablation has been suggested as an alternative to the standard IVC-A, potentially providing improved catheter stability during ablation and thus resulting in higher success rates and lower incidence of complications.12 However, catheter manipulation is complicated and the risk of right bundle branch block and complete atrioventricular block may exist.

Catheter Ablation Strategy for Para-Hisian APs

Ablating para-Hisian APs is challenging because they are in proximity to the normal conduction system. Recently, some studies report successful AP ablation by NCC-A or SVC-A; however, when para-Hisian APs need to mapped and ablated by NCC-A or SVC-A is not well established.13 Xu et al14 reported that radiofrequency ablation delivered in the NCC had a higher success rate (11 of 12 patients). But high ablation energy was needed in most patients and the time needed to achieve AP conduction block was longer (>15–30 s in most patients), so the potential complications and the recurrence rates were unclear. Recently, the complication of complete atrioventricular block was reported by NCC-A.15 On the contrary, 48 of the 55 patients with para-Hisian APs in our study were successfully ablated by IVC-A with lower
Ablation energy, including 9 patients whose initial ablation in the NCC failed to eliminate the APs.

On the basis of the results of the present study, a new catheter ablation strategy for para-Hisian APs can be delineated. If a para-Hisian AP is identified, the degree of fusion between the ventricular and atrial potentials during retrograde AP conduction should be assessed. If the ventricular and atrial potentials are well fused during retrograde AP conduction, the IVC-A should be applied initially. Otherwise, the NCC-A should be used for further mapping and ablation. Mapping and ablation

Figure 3. Fluoroscopic images from a case in the noncoronary cusp approach (NCC-A) group. A and B, Aortic root angiograms taken from a pigtail catheter at the NCC in right anterior oblique projection (RAO) and left anterior oblique projection (LAO) views. C and D, The successful ablation site was located at the NCC at the same fluoroscopic angles before ablation. The successful ablation site is located at the NCC. E, The sites in the NCC adjacent to the right coronary cusp are slightly superior to the His bundle (HB) region by computed tomography. ABL indicates ablation catheter; L, left coronary cusp; N, noncoronary cusp; and R, right coronary cusp.

Figure 4. Intracardiac electrograms during atrioventricular reentrant tachycardia in all 3 patients of the superior vena cava approach group. The ventricular and atrial potentials were fused in the para-Hisian region in case 1, and an isoelectric interval was recorded in case 2 and case 3. ABLd indicates distal bipolar recording; ABLu, unipolar recording; CS, coronary sinus; HISd, HISm, and HISp, distal, middle and proximal electrodes of His bundle recording sites; RHIS, right HIS; and RV right ventricle.
by SVC-A should be considered when ablation by IVC-A and NCC-A fails.

Limitations
In this study, the majority of cases were successfully ablated by IVC-A without an initial attempt by SVC-A. It remains unknown how many of these cases may be successfully ablated through a SVC-A.

Conclusion
Most para-Hisian APs can be safely and effectively ablated by IVC-A, and ablation in the NCC is not an initial or a preferred approach. The degree of ventriculoatrial fusion in the para-Hisian region during retrograde AP conduction can differentiate or predict successful ablation by IVC-A, NCC-A, or SVC-A in most patients with para-Hisian APs.

Disclosures
None.

References

Figure 5. Twelve-lead ECG from 3 group patients showing preexcitation during sinus rhythm. In all these patients, the 12-lead ECG showed a positive delta wave in lead I, II, and aVF, a positive or isoelectric delta wave in lead III, and an isoelectric/negative delta wave in lead V1. AVR, AVL, and AVF indicate leads aVR, aVL and aVF on surface ECG; IVC-A, inferior vena cava approach; and SVC-A, superior vena cava approach.
Different Approaches for Catheter Ablation of Para-Hisian Accessory Pathways: Implications for Mapping and Ablation

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