Journal of Cardiology xxx (2019) xxx–xxx

Contents lists available at ScienceDirect

Journal of Cardiology

journal homepage: www.elsevier.com/locate/jjcc

Original article

Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10 year single-center experience

Tadashi Fujino (MD, PhD)*, Ermengildo De Ruvo (MD), Domenico Grieco (MD), Antonio Scará (MD), Alessio Borrelli (MD), Lucia De Luca (MD), Marco Panuccio (MD), Alessandro Fagagnini (MD), Giuseppe Bruni (MD), Luigi Sciarra (MD), Leonardo Calò (MD)

Division of Cardiology, Policlinico Casilino, Roma, Italy

ARTICLE INFO

Article history:
Received 7 November 2019
Received in revised form 17 April 2020
Accepted 21 April 2020
Available online xxx

Keywords:
Wolff±Parkinson±White syndrome
Catheter ablation
Challenging ablation
Unsuccessful ablation
Outcome

ABSTRACT

Background: Catheter ablation is the established treatment for patients with symptomatic Wolff–Parkinson–White syndrome (WPW). However, some patients undergo a challenging ablation or have recurrences during the early post-ablation phase. The aim of this study was to evaluate the clinical factors associated with an unsuccessful ablation outcome or repeated sessions.

Methods: Four hundred seventy-five symptomatic consecutive WPW patients (38.2 ± 16.2 years old, 61% men, 69% with pre-excitation) who underwent an accessory pathway (AP) ablation from August 2005 to December 2015 were enrolled. When APs recurred, a redo ablation procedure was performed according to the patients' desire.

Results: Four hundred thirty-nine patients (92.4%) were cured by ablation, but it failed in 36 (7.6%) after the first procedure. Seventeen patients had AP recurrences during the acute phase within 36 h post-ablation. On the other hand, 4 were identified after more than one year. In a multivariate logistic regression analysis, multiple, parahisian, and broad APs were significant independent predictors of recurrences after the 1st procedure, with odds ratios of 14.88 ($p < 0.001$), 10.14 ($p < 0.001$), and 6.88 ($p < 0.001$), respectively. Finally, 468 patients (98.5%) received a successful ablation during a mean follow-up of 8.3 ± 3.0 years. However, after the final procedure no significant predictors were recognized. Out of 508 total procedures, three major (0.6%) complications occurred.

Conclusions: Symptomatic WPW patients with multiple, parahisian, and broad APs had a significantly higher risk of recurrence. In half of the recurrence patients, AP recurrences were confirmed during the acute phase, but were rarely recorded in the very late phase.

Introduction

Over the past twenty years, catheter ablation has become an established routine treatment for patients with symptomatic Wolff–Parkinson–White syndrome (WPW) with a high success rate [1] and few complications [2–4]. Current European Heart Rhythm Association and American College of Cardiology Foundation/American Heart Association/Heart Rhythm Society guidelines [5,6] recommend catheter ablation for patients with symptomatic WPW.

As is well known, sudden cardiac death (SCD) rarely occurs in WPW syndrome [4,7], especially in the case of a short effective refractory period (ERP) of the accessary pathway (AP <240 ms) [4,6]. On the contrary, we consider patients with an ERP of the AP of ≥250 ms as 'low-risk' patients. In contemporary treatment, we can choose from several tools such as irrigated-tip catheters, contact-force catheters, cryoenergy, long steerable sheaths, and 3D electroanatomical mapping systems, but the success rate of WPW ablation has not changed. The purpose of the present study was to evaluate the characteristics and clinical factors related to an unsuccessful ablation outcome in patients with symptomatic WPW during the acute and sub-acute phases.

Methods

Study population

Four hundred seventy-five symptomatic consecutive WPW patients (38.2 ± 16.2 years old, 291 men; 61%) who underwent a

* Corresponding author at: Division of Cardiology, Policlinico Casilino, Via Casilina 1049, 00169 Roma, Italy.
E-mail address: fujino1101@med.toho-u.ac.jp (T. Fujino).

https://doi.org/10.1016/j.jjcc.2020.05.003
0914-5087/

catheter ablation procedure to eliminate an AP at our institution between August 2005 and December 2015 were enrolled in this study. Those patients had many symptoms (more than once every three months). The patients with a history of a previous radiofrequency catheter ablation (RFCA) for an AP were excluded. In addition, low-risk patients (with ERP >250 ms) were not included. In total, 329 patients (69%) had manifest pre-excitation and 146 patients (31%) did not. All operators had performed more than 100 WPW ablation cases.

All patients gave their written informed consent for the study protocol, which was approved by the institutional review boards.

Electrophysiological study before the ablation procedure

All antiarrhythmic drugs (AADs) including beta-blockers were discontinued for at least 7 days before the ablation. The surface electrocardiograms (ECGs) and bipolar intracardiac electrograms were continuously monitored and stored on a computer-based digital recording system [LabSystem PRO (Bard Electrophysiology, Lowell, MA, USA)]. The bipolar electrograms were filtered from 30 to 500 Hz. A 6-Fr 10-pole catheter was inserted through the right femoral vein and positioned in the coronary sinus for pacing and recording. A 6-Fr 4-pole catheter was inserted through the left femoral vein and placed at the His bundle region and in the right ventricle for pacing and recording.

If patients had left-sided APs, a transaortic approach was performed in the early years while a transseptal approach was used more often in the more recent years according to the physician's preference. In addition, we did not use any heparin regardless of the AP location until 2006, but after having experienced two transient ischemic attacks (TIAs) a 5000 IU intravenous bolus of heparin was administered just after the femoral puncture.

Catheter ablation procedure

At first, radiofrequency (RF) energy was delivered with a 4-mm non-irrigated tip ablation catheter (Blazer^{TM}II; Boston Scientific, San Jose, CA, USA for right sided ablation or Celsius; Biosense Webster, Diamond Bar, CA, USA for left sided ablation). When a para-Hisian location of the AP was found, a 7-Fr 6-mm electrode tip cryoablation catheter (Freezor® Xtra, CryoCath; Medtronic Inc., Minneapolis, MN, USA) was used. For epicardial cases, ablation within the coronary sinus (CS) was performed for a maximum of 25 W and 40 s. Selective venography of the CS was also used in some cases in order to achieve successful ablation.

When the AP disappeared within 10 s, the RF energy delivery was maintained for 60 s. On the contrary, when the AP did not disappear within 10 s, the RF energy delivery was stopped immediately. Further, in the case of an early recurrence after a few applications, an irrigated tip ablation catheter was preferred (Thermocool; Biosense Webster). In addition, if we identified poor catheter stability during the ablation, we facilitated the catheter stability through the use of long sheaths (8.5-Fr SL-0 or Agilis; AF Division, St. Jude Medical, St. Paul, MN, USA), especially for right-sided APs.

With the non-irrigated tip ablation catheter, the RF energy was delivered for 60 s for all applications (50 W, 55–60 °C), while we used a maximum output of 25–30 W for the irrigated tip ablation catheter (irrigation flow rate of 17–30 mL/min during the RF delivery).

The endpoint of the ablation was the elimination of all APs. After the ablation an intravenous injection of adenosine triphosphate (ATP) was infused in all cases except for patients with documented asthma. Moreover, in challenging cases, an isoproterenol infusion (starting at 1 μg/min for 2 min) was also given after the procedure, and was limited only by patient intolerance, hypotension, or the appearance of delta waves. In all patients, the absence of the AP was confirmed after a waiting period of 30 min from the final energy application.

In the case of a WPW recurrence, the ablation was performed using an alternative approach (irrigated tip catheter vs. solid tip catheter, transseptal vs. transaortic, steerable sheath or a 3D mapping system). In almost all cases, no electro-anatomical mapping system was used during the first procedure.

Postablation follow-up

A 12-lead ECG was obtained before hospital discharge. The patients were followed up at 1, 3, 6, and 12 months after the procedure, and then every 12 months. We judged the disappearance of the delta wave or symptoms associated with a tachycardia as a successful ablation. Recurrence was assessed on the basis of the patient's symptoms in conjunction with serial 12-lead ECGs or 24-h Holter ECGs. Overall, the patients were followed-up for 8.3 ± 3.0 years.

Reappearance of delta waves or paroxysmal episodes of a regular narrow QRS tachycardia after the ablation were considered as a recurrence, and a repeat procedure was performed.

Statistical analysis

Continuous variables are expressed as the mean ± standard deviation or median (25–75%) value. The differences in the continuous variables between the two (unsuccessful and successful) groups were compared by an unpaired *t*-test or Mann–Whitney test per the data distribution (normal or not), and for the categorical variables the differences were investigated with a Fisher's exact test. A binary regression analysis was performed to identify the predictors of an unsuccessful ablation outcome in the WPW patients and to calculate the odds ratio (OR) and 95% confidence intervals (95% CI). Univariate and multivariate binary regression analyses were performed without and with an adjustment for the other variables. For the comparisons between the unsuccessful and successful groups, variables with a $p < 0.05$ were selected and adopted for a multiple binary regression model. In the case of collinearity characteristics between the 2 variables, either of the two variables were excluded from the multiple regression model. All statistical analyses were performed using SPSS (IBM, Armonk, NY, USA) version 18.0 software, and a $p < 0.05$ was considered statistically significant.

Results

Patient characteristics

The characteristics of the symptomatic WPW patients are shown in Table 1. Among them, 329 patients (69%) had pre-excitation and 146 (31%) did not. The mean age was 38.2 ± 16.2 years and 291 (61%) were male. Seventy-two patients (15%) younger than 20 years were included. However, there were 6 patients (1.3%) more than 75 years old. Forty-one patients (8.6%) had atrial fibrillation (AF) and 244 (51%) had atrioventricular reentrant tachycardia (AVRT) before the ablation. The mean ERP of the AP was 277.6 ± 57.2 ms. The mean left ventricular ejection fraction by echocardiography was 57.3 ± 7.4%. Three patients (0.6%) had an Ebstein's anomaly. We used a 3D mapping system only in 47 patients (presence with $n = 47$ vs. without $n = 428$, $p = 0.366$).

Locations of the APs

The locations of the APs are shown in Fig. 1. All patients were classified into 3 groups according to the locations of the APs: left-

Please cite this article in press as: Fujino T, et al. Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10 ?year single-center experience. J Cardiol (2020), https://doi.org/10.1016/j.jjcc.2020.05.003

Table 1
Characteristics of the WPW patients.

Age (years)	38.2 ± 16.2
<20 years old (%)	72 (15.2)
≥75 years old (%)	6 (1.3)
Gender, male/female	291 (61.3)/184 (38.7)
AP with pre-excitation involving intermittent (%)	329 (69.2)
AP with intermittent pre-excitation (%)	56 (11.8)
Presence of structural heart diseases (%)	3 (0.6)
Left-sided AP (%)	233 (49.1)
Right-sided AP (%)	36 (7.6)
Septal AP (%)	210 (44.2)
- ParahisianAP (%)	14 (2.9)
- InferoseptalAP (%)	181 (38.1)
Broad AP (%)	24 (5.1)
Multiple AP (%)	12 (2.5)
Epicardial AP (%)	7 (1.5)
With AF (%)	41 (8.6)
With AVRT (%)	244 (51.4)
LVEF (%)	57.3 ± 7.4
AP-ERP (ms)	277.6 ± 57.2
Procedure time (min)	147.3 ± 49.5
Fluoroscopy time (min)	19.9 ± 16.4
No. of ablation sessions	1.07 ± 0.3
1/2/3 sessions	445/27/3

Data are expressed as the mean ± standard deviation, median (25%–75%), or number (%). AP, accessory pathway; AF, atrial fibrillation; AVRT, atrioventricular reentrant tachycardia; LVEF, left ventricular ejection fraction; ERP, effective refractory period; WPW, Wolff–Parkinson–White syndrome.

sided APs (n = 233, 49%), right-sided APs (n = 36, 7.6%), and septal APs (n = 210, 44%). Moreover, we divided the APs into right- or left-sided superior, anterosuperior, anterior, anteroinferior, inferior, posterosuperior, posterior, posteroinferior, superoseptal, midseptal, and right- or left-sided inferoseptal APs as shown in Fig. 1. In addition, parahisian, multiple, broad, or epicardial APs were observed in 14 (2.9%), 12 (2.5%), 24 (5.1%), and 7 (1.5%) patients, respectively. In this study, we defined 'multiple' APs as discontinuous APs separated more by than 2 cm, and 'broad' APs as continuous APs that needed ablation at more than 3 close sites.

In patients without pre-excitation, 126 (82%) of 153 APs were located on the left-side as shown in Fig. 2. In addition, most concealed APs were considerably located at the mitral valve between 2 to 6 o'clock. Finally, all 146 patients were cured by one (n = 140, 96%) or two (n = 6, 4%) ablation sessions.

AP ablation outcomes

During the first session, ablation was successful in 439 patients (92.4%) and failed in 36 (7.6%). We were not able to treat an inferoseptal AP during the first session in only one case and that patient refused a re-do procedure. After the first session, 34 (94.4%) out of 36 patients with a recurrence underwent a repeat ablation. A 2nd and 3rd ablation session was performed in 31 (6.5%) and 3 (0.6%) patients, respectively.

During a mean follow-up of 8.3 ± 3.0 years, 468 patients (98.5%) finally received a successful ablation without any AADs after the final session. Only seven patients (1.5%) were not cured by ablation. Delta waves could be recognized in five patients, but all patients remained asymptomatic.

After the 1st session, Table 2 shows a comparison between the patients with a successful and unsuccessful ablation after the 1st session. The univariate logistic regression analyses revealed that epicardial APs, parahisian APs, broad APs, multiple APs, right-sided APs, left-sided APs, the procedure time, manifest APs, the fluoroscopy time, and younger patients were significant predictors of an AP recurrence after the initial ablation procedure ($p < 0.001$, $p < 0.001$, $p = 0.001$, $p = 0.001$, $p = 0.003$, $p = 0.003$, $p = 0.015$, $p = 0.024$, $p = 0.033$, $p = 0.048$, respectively; Table 2). In the binary multivariate logistic regression analysis multiple APs, a parahisian AP location, and broad APs were significant independent predictors of recurrences, with odds ratios of 14.88 (95% CI, 3.89–56.93; $p < 0.001$), 10.14 (95% CI, 2.89–35.66; $p < 0.001$), and 6.88 (95% CI, 2.33–20.27; $p < 0.001$, Table 3), respectively.

After the final session, univariate logistic regression analyses revealed that the procedure time, fluoroscopy time, and multiple APs were significant predictors of an AP recurrence after the final ablation procedure ($p < 0.001$, $p = 0.003$, $p = 0.012$). However, there were no significant independent predictors in the multivariate logistic regression analyses. Of them, multiple APs had a higher recurrence ($p = 0.078$).

Time course to the AP recurrence

As shown in Fig. 3, the 35 AP recurrences were classified into 3 groups. Seventeen (48.6%) of the 35 patients had a recurrence within 36 h, mostly within 24 h (15, 42.9%). Fourteen (40%) had a recurrence between 6 days and 6 months, and 4 (11.4%) were identified after more than one year. The latest recurrence was identified after two years and eight months from the initial ablation. However, there were no significant predictors of an acute recurrence within 36 h.

Major procedural complications

Major complications occurred in only three left-sided AP patients (0.6%). A mild pericardial effusion (not requiring drainage) was observed in one patient. Two other patients developed TIAs, which completely recovered within 24 h. In the present study, no patients suffered from AV block after the ablation in spite of 11 patients having parahisian APs. Furthermore, no aborted sudden cardiac death or ventricular fibrillation occurred during the follow-up.

Discussion

Main findings

The main findings of the present study were: first, in symptomatic WPW patients, catheter ablation of APs achieved a successful outcome of 98.5% without any AADs; second, the multivariate logistic regression analysis showed that multiple, parahisian, and broad APs were associated with an unsuccessful ablation outcome after the initial ablation; and third, in half of the patients with a recurrence, conduction over the AP was recorded during the acute phase and within three days, but rarely were recorded during the very late phase.

Association between multiple and/or broad APs and a failed ablation

Multiple APs have been identified in 3–14% of patients undergoing an electrophysiological study [8–10]. A broad AP may have two or more APs, or an oblique course of the APs. The past literature reported that many APs may have broad atrial or ventricular insertions [11]. In our study, multiple APs were identified in 12 patients (2.5%) and broad APs in 24 (5.1%), for a total of 36 patients (7.6%). One patient had three APs. Almost all of the previous publications did not classify these two separately, but we divided them into separate groups. Both broad and multiple APs may mean there could be an easier recurrence, and they were significant independent predictors of a recurrence.

In past reports, multiple and/or large pathways may have been much more challenging, but those reports were not able to prove that [12–15]. Iturralde et al. demonstrated that the success rate in

Please cite this article in press as: Fujino T, et al. Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10 2year single-center experience. J Cardiol (2020), https://doi.org/10.1016/j.jjcc.2020.05.003

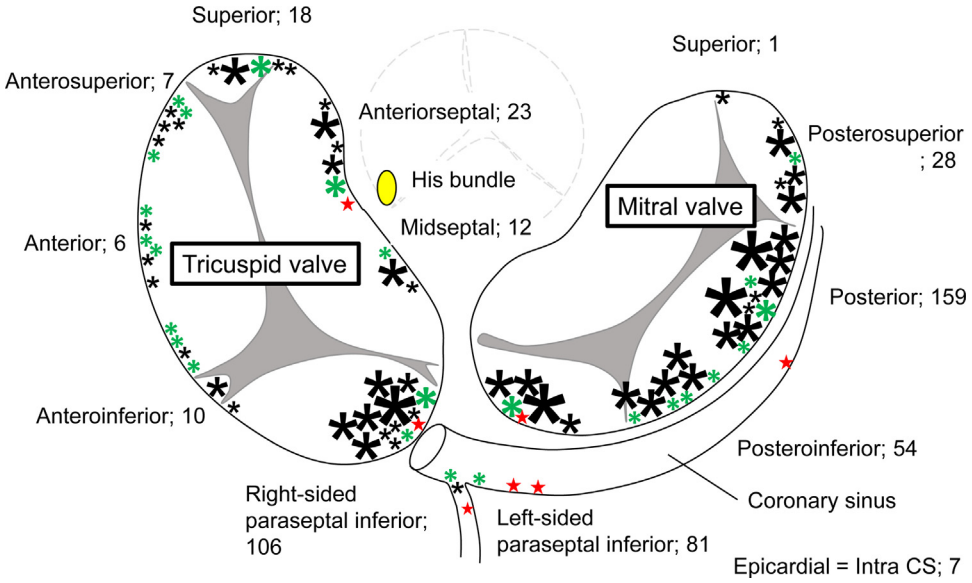

Fig. 1. Diagram of the locations of 512 APs among all 475 WPW patients. The numbers indicate each location of the APs. The biggest five-pointed asterisks indicate 50 cases, big five-pointed asterisks 10, normal five-pointed asterisks 5, and small five-pointed asterisks 1. Furthermore, the black five-pointed asterisks indicate the successful sites, green six-pointed asterisks subacute recurrence sites and red stars failure sites. WPW, Wolff–Parkinson–White syndrome; AP, accessory pathway.

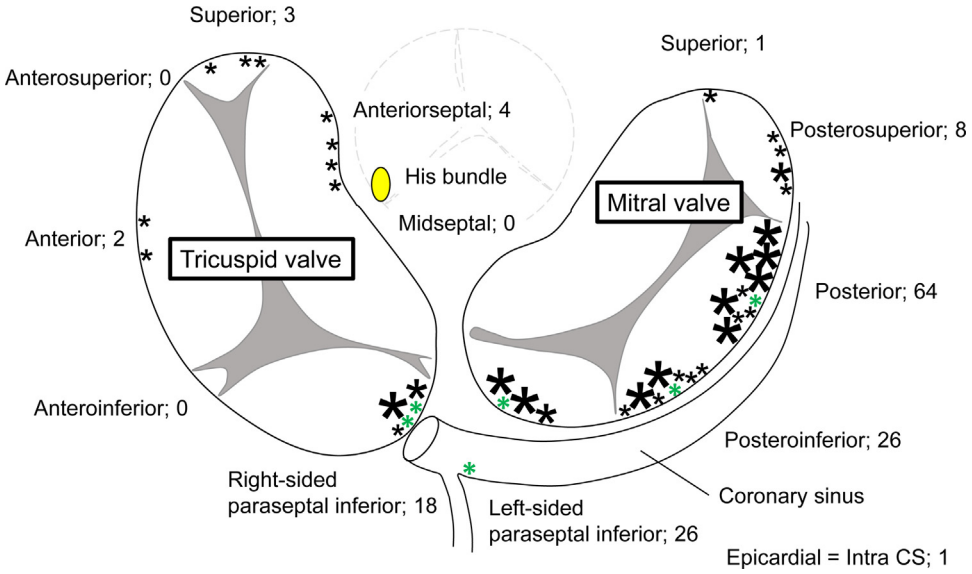

Fig. 2. Diagram of the locations of 153 APs among 146 concealed patients. The numbers indicate each location of the APs. The big five-pointed asterisks indicate 10 cases, normal 5, and small 1. Furthermore, the black five-pointed asterisks indicate successful sites and green six-pointed asterisks subacute recurrence sites. AP, accessory pathway.

patients with multiple APs is lower than that in those with a single AP during only one session (81% vs. 93%, $p < 0.01$) [9].

In addition, past studies reported that patients with multiple APs are associated with an increased risk of SCD [4,7]. Therefore, it is important to eliminate multiple APs by any ablation method necessary. As a result of this study, it was suggested that it is necessary to ablate more widely and completely, and that additional ablation may be needed as well. If multiple or broad APs are identified, you should wait for 60 min after the final energy application in order to avoid any AP recurrence. Although of course an ECG algorithm may be useful for the detection of multiple APs [16], when multiple APs are suspected we recommend using a 3D mapping system.

Association between parahisian APs and failure

Out of all WPW patients, 1.4–1.6% of the patients had parahisian pathways [17,18], but our study included 14 patients (2.9%). Gaita et al. previously reported that cryoablation appears to be a safe and effective technique for ablation of APs close to the AV node or His bundle and that it has acute effects [19]. Generally, parahisian APs have a higher incidence of recurrence (11–25%) [18,20]. Finally, 13 patients with parahisian APs (92.9%), except for one case, were completely cured by using a cryoablation catheter. However, six patients (42.8%) had an unsuccessful ablation in the initial session.

Complications (involving 1st degree AV block) may occur in 2–10% during the ablation [18]. In our series, no patients suffered

Please cite this article in press as: Fujino T, et al. Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10 ?year single-center experience. J Cardiol (2020), https://doi.org/10.1016/j.jjcc.2020.05.003

Table 2
Comparison of the patient characteristics between the successful and unsuccessful groups after the 1st session.

	All cases $N=475$	Unsuccessful $N=36$	Successful $N=439$	p-Values
Age, years	38.2 ± 16.2	35.1 ± 17.4	38.4 ± 16.1	0.232[a]
Age < 20 years old (%)	72 (15.2)	10 (27.8)	62 (14.1)	0.048[b]
Male (%)	184 (61.3)	22 (61.1)	269 (61.3)	0.999[b]
AP with pre-excitation (%)	329 (69.3)	31 (86.1)	298 (67.9)	0.024[b]
AP with intermittent pre-excitation (%)	56 (11.8)	5 (13.9)	51 (11.6)	0.598[b]
Left-sided AP (%)	233 (49.1)	9 (25.0)	224 (51.0)	0.003[b]
Right-sided AP (%)	36 (7.6)	8 (22.2)	28 (6.4)	0.003[b]
Septal AP (%)	210 (44.2)	17 (47.2)	193 (44.0)	0.730[b]
- Parahisian AP (%)	14 (2.9)	6 (16.7)	8 (1.8)	<0.001[b]
- Inferoseptal AP (%)	181 (38.1)	10 (27.8)	171 (39.0)	0.214[b]
Broad AP (%)	24 (5.1)	7 (19.4)	17 (3.9)	0.001[b]
Multiple AP (%)	12 (2.5)	5 (13.9)	7 (1.6)	0.001[b]
Epicardial AP (%)	7 (1.5)	6 (16.7)	1 (0.2)	<0.001[b]
With AF (%)	41 (8.6)	4 (11.1)	37 (8.4)	0.538[b]
With AVRT (%)	244 (51.4)	15 (11.1)	229 (52.2)	0.298[b]
LVEF (%)	57.3 ± 7.4	62.0 ± 4.5	56.3 ± 7.6	0.121[a]
AP-ERP, ms	278 ± 57	296 ± 70	276 ± 56	0.326[a]
Procedure time, min	147 ± 49	174 ± 56	144 ± 48	0.015[a]
Fluoroscopy time, min	15.0 [9.0–26.0]	28.0 [9.0–26.0]	15.0 [9.0–24.0]	0.033[c]

The data are expressed as the mean ± standard deviation or median (25%–75%), or number (%). AP, accessory pathway; AF, atrial fibrillation; AVRT, atrioventricular reentrant tachycardia; LVEF, left ventricular ejection fraction; ERP, effective refractory period.
The p-values were determined by
[a] An unpaired t test.
[b] Fisher's exact test.
[c] Mann–Whitney test.

Table 3
Predictors of an unsuccessful ablation outcome in the patients with WPW syndrome determined by binary logistic regression analyses.

Variables	Before adjustment		After adjustment	
	OR (95% CI)	p-Values	OR (95% CI)	p-Values
Age <20 years old	2.34 (1.08–5.09)	0.032	1.75 (0.70–4.33)	0.230
AP with pre-excitation	2.93 (1.12–7.70)	0.029	1.84 (0.65–5.21)	0.248
Left-sided AP	0.32 (0.15–0.70)	0.004	0.49 (0.20–1.21)	0.120
Right-sided AP	4.19 (1.75–10.05)	0.001	2.02 (0.69–5.94)	0.199
Parahisian AP	10.77 (3.51–33.07)	<0.001	10.14 (2.89–35.66)	<0.001
Broad AP	5.99 (2.30–15.61)	<0.001	6.88 (2.33–20.27)	<0.001
Multiple AP	9.95 (2.99–33.18)	<0.001	14.88 (3.89–56.93)	<0.001
Procedure <147 min[a]	2.00 (0.75–5.35)	0.165	Not apply	
Fluoroscope <15 min[b]	1.50 (0.55–4.05)	0.427	Not apply	

The chi-square value was 5.64 for the Hosmer–Lemeshow test ($p = 0.464$). WPW, Wolff–Parkinson–White syndrome; OR, odds ratio; CI, confidential interval; AP, accessory pathway.
[a] The mean value.
[b] Median value of all cases.

from any complications (involving 1st degree AV block) after the parahisian ablation.

Predictors of AP recurrence

Several clinical factors can predict the recurrence of AP conduction. The past reports could not find any predictors for the reappearance of the AP conduction after ablation because of the lower AP recurrences. However, although there were no significant predictors, some reports have shown a higher recurrence rate after the initial ablation of right free wall APs [14,21–23], inferoseptal APs [21,23], and a prolonged procedure time [24]. An unstable catheter position and possible epicardial pathway location are the main contributing factors for a primary failure [23]. In the modern era, the ablation of anterior (right free wall) APs has mainly been solved by using long steerable sheaths and technologies such as 3D mapping systems. Some of the reports have demonstrated that catheter manipulation [15,24] and inaccurate mapping have led to AP recurrences [15]. Naturally, the procedure time will become longer when we perform ablation in challenging cases such as those with an Ebstein's anomaly or poor stability of the catheter. We believed that structural heart disease (SHD) was not a predictor of an AP recurrence because only three patients had SHD in this study. In addition, Langberg et al. reported that younger patients had a higher incidence of multiple APs with recurrences [22].

As Fig. 1 shows, in our experience, we had more difficulty ablating inferoseptal APs. We also thought that inferoseptal APs exist in deep myocardial sites as previously reported [15,25]. Further, the use of irrigated-tip catheters was also important. A radical cure could finally be achieved by multiple ablation sessions from both the right and left sides as well as CS applications [15]. In fact, in 4 patients with APs in those areas a complete disappearance of the AP could not be achieved (Fig. 1).

Incidence and timing of AP recurrences

The incidence of AP recurrences was usually within 2–3 months. In particular, the main recurrence period occurs during the acute phase within 12 h as previously reported [22,24]. Our

Please cite this article in press as: Fujino T, et al. Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10 2year single-center experience. J Cardiol (2020), https://doi.org/10.1016/j.jjcc.2020.05.003

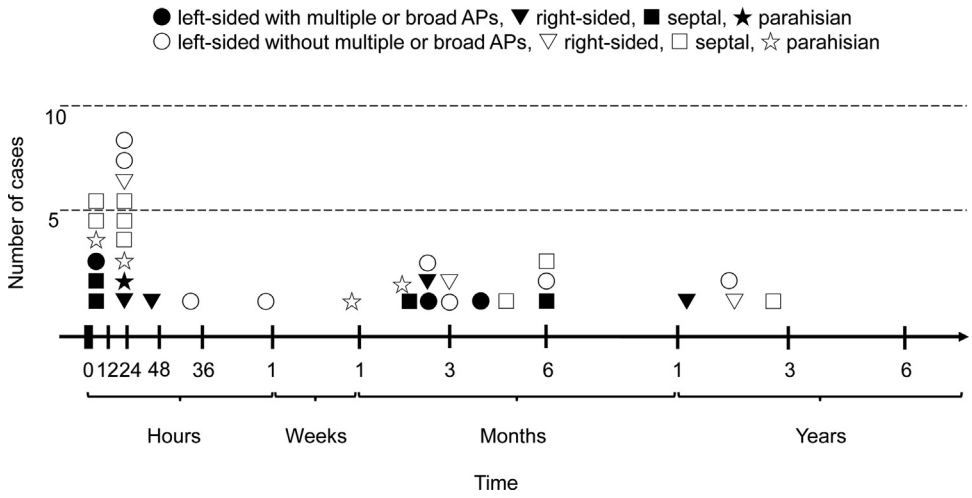

Fig. 3. Time course of the onset of the first recurrence after the 1st session in 35 WPW recurrent patients. The circle indicates a left-sided AP, triangle a right-sided AP, square a septal AP, and star a parahisian AP. Furthermore, the black indicates multiple or broad APs and white no multiple or broad APs. WPW, Wolff–Parkinson–White syndrome; AP, accessory pathway.

data also showed that AP reconnections before hospital discharge were associated with symptoms in 15 patients (42.8%).

We defined a late AP recurrence as an AP recurrence >12 months after the initial catheter ablation. In our study only 4 patients out of 36 had a late AP recurrence (11.4%, Fig. 3). Although most reports have found that the recurrence of the AP conduction was documented within 6 months after the ablation [12,14,22,24], only one report found AP recurrences after 6 months in 25% (14 out of 46) [3]. However, that report did not report it in detail. In the present study, only 2 AVRTs with delta waves on the basal ECG were confirmed in 2 asymptomatic patients during the follow-up. It is difficult to detect a diagnosis of an AP recurrence when patients have no symptoms after the ablation. Therefore, from our results, operators should observe the patients for at least three years.

AP recurrence rate after the initial and final sessions

AP recurrences were identified in 23–29% of patients in the era of high voltage direct current ablation for APs [24,26]. According to the previous reports, the incidence of an AP recurrence is 6–12% [2,3,12,14,22,27]. Our AP recurrence rate was 7.6% (36 of 475), similar to the previous reports from the 1990s [2,3,12,14,22,27] and a more recent study [15].

In spite of the improvement in medical devices, the success rate of WPW ablation after 2000, including our study, has mostly been as well as that of the 1990s. However, almost all the patients (98.5%; 468 of 475) were finally cured by multiple ablation sessions. Another six patients had no symptoms without AADs. We thought they would have no attacks of arrhythmias because the manifest AP conduction had become poor due to the ablation. As our results have shown, if you can sufficiently determine the characteristics of the AP, which should be easy to do before the ablation, it is possible that the success rate of the WPW ablation will rise in the near future.

Complication rates

Major complications associated with the ablation procedure have been very low at 1–2% [3,4] and similar to that in our study. Eventually, although we performed a total of 508 sessions to eliminate the APs, only 0.6% of the patients suffered from major complications. Further, we did not experience any complications after more than 10 years. Particularly, we guessed that the use of heparin prevented TIAs in left-sided AP patients. Certainly, lower complications will be achieved from the vast information from many publications, shorter procedure times, and experience gained with a greater number of ablation cases. As a result, we were able to prove the rise in the success rate and confirmed that the complications have clearly decreased in comparison to that in the past.

Study limitations

This study had some potential limitations. First, it was a retrospective and observational study. Second, this study was a single center study, which might have caused a statistical bias. Third, the number of subjects may have been relatively low.

Conclusions

WPW syndrome patients can be safely cured by trans-catheter ablation with a high success rate and low rate of major complications. Symptomatic WPW patients with parahisian, multiple, and broad APs had a significantly higher risk of recurrence. In half of those patients, AP recurrences were confirmed during the acute phase within three days, but rarely could be recorded during the very late phase.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgment

We thank Takahito Kaji for his help with checking the statistical analyses.

References

[1] Jackman WM, Wang XZ, Friday KJ, Roman CA, Moulton KP, Beckman KJ, et al. Catheter ablation of accessory atrioventricular pathways (Wolff–Parkinson–White syndrome) by radiofrequency current. N Engl J Med 1991;324:1605–11.
[2] Calkins H, Yong P, Miller JM, Olshansky B, Carlson M, Saul JP, et al. Catheter ablation of accessory pathways, atrioventricular nodal reentrant tachycardia, and the atrioventricular junction: final results of a prospective, multicenter clinical trial. Circulation 1999;99:262–70.
[3] Dagres N, Clague JR, Kottkamp H, Hindricks G, Breithardt G, Borggrefe M. Radiofrequency catheter ablation of accessory pathways. Outcome and use of antiarrhythmic drugs during follow-up. Eur Heart J 1999;20:1826–32.

Please cite this article in press as: Fujino T, et al. Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10 ?year single-center experience. J Cardiol (2020), https://doi.org/10.1016/j.jjcc.2020.05.003

[4] Pappone C, Vicedomini G, Manguso F, Saviano M, Baldi M, Pappone A, et al. Wolff–Parkinson–White syndrome in the era of catheter ablation: insights from a registry study of 2169 patients. Circulation 2014;130:811–9.
[5] Page RL, Joglar JA, Caldwell MA, Calkins H, Conti JB, Deal BJ, et al. 2015 ACC/AHA/HRS Guideline for the Management of Adult Patients With Supraventricular Tachycardia: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society. Circulation 2016;133:e506–74.
[6] Cohen MI, Triedman JK, Cannon BC, Davis AM, Drago F, Janousek J, et al. PACES/HRS expert consensus statement on the management of the asymptomatic young patient with a Wolff–Parkinson–White (WPW, ventricular preexcitation) electrocardiographic pattern: developed in partnership between the Pediatric and Congenital Electrophysiology Society (PACES) and the Heart Rhythm Society (HRS). Endorsed by the governing bodies of PACES, HRS, the American College of Cardiology Foundation (ACCF), the American Heart Association (AHA), the American Academy of Pediatrics (AAP), and the Canadian Heart Rhythm Society (CHRS). Heart Rhythm 2012;9:1006–24.
[7] Timmermans C, Smeets JL, Rodriguez LM, Vrouchos G, van den Dool A, Wellens HJ. Aborted sudden death in the Wolff–Parkinson–White syndrome. Am J Cardiol 1995;76:492–4.
[8] Chen SA, Hsia CP, Chiang CE, Chiou CW, Yang CJ, Cheng CC, et al. Reappraisal of radiofrequency ablation of multiple accessory pathways. Am Heart J 1993;125:760–71.
[9] Iturralde P, Guevara-Valdivia M, Rodriguez-Chavez L, Medeiros A, Colin L. Radiofrequency ablation of multiple accessory pathways. Europace 2002;4:273–80.
[10] Yeh SJ, Wang CC, Wen MS, Lin FC, Wu D. Radiofrequency ablation in multiple accessory pathways and the physiologic implications. Am J Cardiol 1993;71:1174–80.
[11] Lev M, Kennamer R, Prinzmetal M, De Mesquita QH. A histopathologic study of the atrioventricular communications in two hearts with the Wolff–Parkinson–White syndrome. Circulation 1961;24:41–50.
[12] Twidale N, Wang XZ, Beckman KJ, McClelland JH, Moulton KP, Prior MI, et al. Factors associated with recurrence of accessory pathway conduction after radiofrequency catheter ablation. Pacing Clin Electrophysiol 1991;14:2042–8.
[13] Chen SA, Chiang CE, Tsang WP, Hsia CP, Wang DC, Yeh HI, et al. Recurrent conduction in accessory pathway and possible new arrhythmias after radiofrequency catheter ablation. Am Heart J 1993;125:381–7.
[14] Timmermans C, Smeets JL, Rodriguez LM, Oreto G, Medina E, Notheis W, et al. Recurrence rate after accessory pathway ablation. Br Heart J 1994;72:571–4.
[15] Sacher F, Wright M, Tedrow UB, O'Neill MD, Jais P, Hocini M, et al. Wolff–Parkinson–White ablation after a prior failure: a 7-year multicentre experience. Europace 2010;12:835–41.
[16] Wellens HJ, Atié J, Smeets JL, Cruz FE, Gorgels AP, Brugada P. The electrocardiogram in patients with multiple accessory atrioventricular pathways. J Am Coll Cardiol 1990;16:745–51.
[17] Haissaguerre M, Marcus F, Poquet F, Gencel L, Le Métayer P, Clémenty J. Electrocardiographic characteristics and catheter ablation of parahissian accessory pathways. Circulation 1994;90:1124–8.
[18] Tai CT, Chen SA, Chiang CE, Lee SH, Chang MS. Electrocardiographic and electrophysiologic characteristics of anteroseptal, midseptal, and para-Hisian accessory pathways. Implication for radiofrequency catheter ablation. Chest 1996;109:730–40.
[19] Gaita F, Haissaguerre M, Giustetto C, Grossi S, Caruzzo E, Bianchi F, et al. Safety and efficacy of cryoablation of accessory pathways adjacent to the normal conduction system. J Cardiovasc Electrophysiol 2003;14:825–9.
[20] Lorga Filho A, Sosa E, Scanavacca M, d'Avila A, Kuniyoshi R, de Horta J, et al. Electrocardiographic identification of mid-septal accessory pathways in close proximity to the atrioventricular conduction system. Pacing Clin Electrophysiol 1996;19:1984–7.
[21] Schläpfer J, Fromer M. Late clinical outcome after successful radiofrequency catheter ablation of accessory pathways. Eur Heart J 2001;22:605–9.
[22] Langberg JJ, Calkins H, Kim YN, Sousa J, el-Atassi R, Leon A, et al. Recurrence of conduction in accessory atrioventricular connections after initially successful radiofrequency catheter ablation. J Am Coll Cardiol 1992;19:1588–92.
[23] Kay GN, Epstein AE, Dailey SM, Plumb VJ. Role of radiofrequency ablation in the management of supraventricular arrhythmias: experience in 760 consecutive patients. J Cardiovasc Electrophysiol 1993;4:371–89.
[24] Morady F, Strickberger A, Man KC, Daoud E, Niebauer M, Goyal R, et al. Reasons for prolonged or failed attempts at radiofrequency catheter ablation of accessory pathways. J Am Coll Cardiol 1996;27:683–9.
[25] Selle JG, Sealy WC, Gallagher JJ, Svenson RH, Zimmern SH, Fedor JM, et al. The complex posterior septal space in the Wolff–Parkinson–White syndrome. Surgical experience with 47 patients. Thorac Cardiovasc Surg 1989;37:299–304.
[26] Scheinman M, Calkins H, Gillette P, Klein R, Lerman BB, Morady F, et al. NASPE policy statement on catheter ablation: personnel, policy, procedures, and therapeutic recommendations. Pacing Clin Electrophysiol 2003;26:789–99.
[27] Xie B, Heald SC, Camm AJ, Rowland E, Ward DE. Radiofrequency catheter ablation of accessory atrioventricular pathways: primary failure and recurrence of conduction. Heart 1997;77:363–8.

Please cite this article in press as: Fujino T, et al. Clinical characteristics of challenging catheter ablation procedures in patients with WPW syndrome: A 10-year single-center experience. J Cardiol (2020), https://doi.org/10.1016/j.jjcc.2020.05.003