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Conventional-Power Conventional-Duration versus High-Power Short-Duration Radiofrequency Ablation in Same Lesion Size Index-Guided Pulmonary Vein Isolation

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Abstract

Background: Pulmonary vein isolation (PVI) is used for treating atrial fibrillation, and high-power, short-duration (HP-SD) radiofrequency ablation is considered effective. The depth of myocardial scar in HP-SD ablation is shallower than that in conventional-power, conventional-duration (CP-CD) ablation, and this can be a possible limitation. Hence, the current study aimed to investigate the differences between CP-CD and HP-SD ablation.

Methods: Retrospective analyses were performed on patients who received PVI at Fujigaoka Hospital between May 2018 and June 2020. All electroanatomic mapping was performed using EnSite-PrecisionTM cardiac mapping system (Abbott). In both methods, PVI was performed under the same lesion size index (LSI) guidance. The pulmonary veins (PVs) on both sides were divided into six segments (anterior, posterior, roof, bottom, and anterior and posterior parts of the carina). The characteristics of patients and procedures, remnant conduction and early reconnections of the PV after the initial PVI, and clinical outcomes were compared between the CP-CD and HP-SD groups.

Results: 200 consecutive patients who underwent same lesion size index-guided PVI were enrolled. The first half of consecutive patients (n = 100) underwent CP-CD ablation, and the second half (n = 100) underwent HP-SD ablation. The CP-CD group had a significantly longer procedure time than the HP-SD group. The remnant conduction and early reconnections in the right anterior carina were significantly less common in the CP-CD group than in the HP-SD group. The 2-year cumulative recurrence rate of all types of atrial fibrillation was comparable between the CP-CD and HP-SD groups.

Conclusions: CP-CD and HP-SD radiofrequency ablation had distinct features. Combined CP-CD and HP-SD based on the PV segment, particularly the right PV anterior carina, might be a reasonable approach.

Introduction

Pulmonary vein isolation (PVI) is a standard treatment for paroxysmal and persistent atrial fibrillation (AF) [1]. With the development of contact force-sensing technology, radiofrequency ablation can now create more continuous and penetrating ablation lines [2-5]. However, the recurrence rate of AF remains significant, possibly due to the reappearance of pulmonary venous conduction [6-8]. High-power, short-duration (HP-SD) ablation is a novel standard method that can establish more continuous ablation lines than conventional-power, conventional-duration (CP-CD) ablation [9, 10]. The long-term recurrence rates of AF after HP-SD ablation is similar to or better than those of AF after CP-CD ablation [11, 12].

Key Words

High-Power Short-Duration, Conventional-Power Conventioal-Duration, Atrial Fibrillation, Catheter Ablation

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However, some studies have reported that the depth of myocardial scar created by HP-SD ablation is shallower than that created by conventional CP-CD ablation [13, 14], and this can lead to pulmonary vein (PV) reconnections. This phenomenon is dependent on anatomical features. For example, the posterior wall of the left atrial myocardium is thin, and the mitral annulus and septal side of the right PV are thick [15].

Therefore, the current study aimed to investigate the differences between CP-CD and HP-SD ablation.

Methods

This was a single-center, retrospective study performed on patients who received PVI at Fujigaoka Hospital between May 2018 and June 2020. Treatment was interrupted at least five half-lives preablation in patients taking antiarrhythmic drugs. All patients were followed-up at 1, 3, 6, and 12 months postoperatively. Patients who were followed-up underwent 24-h Holter electrocardiography (ECG) and 12-lead ECG. Moreover, those who presented with AF recurrence within 3 months postablation received antiarrhythmic therapy, which was then

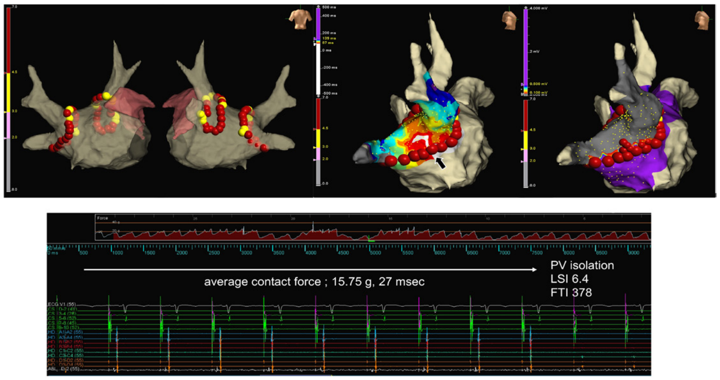

Figure 1: Remnant conduction in the right PV anterior carina using HP-SD ablation. The presence of remnant conduction and early reconnections after the initial ablation was assessed with an ablation catheter, 20-pole ring catheter, or HD Grid catheter. If remnant conduction and early reconnections were observed, additional radiofrequency applications were performed in that area in CP-CD ablation. PV: pulmonary vein, HP-SD: high-power, short-duration, CP-CD: conventional-power, conventional-duration

discontinued after a blanking period of 90 days. AF recurrence was defined as the presence of atrial tachycardia, flutter, or AF (lasting > 30 s) 90 days after ablation.

Ablation method

Table 1 shows the procedure for each method. Figure 1 depicts the representative ablation lines. Contact force ablation was performed with TactiCath™ Contact Force Ablation Catheter, Sensor Enabled™ (Abbott, St. Paul, MN, the USA) along with EnSite-PrecisionTM cardiac mapping system (Abbott). Two sheaths were utilized for transseptal puncture. A bidirectional steerable transseptal guiding sheath (Agilis™ NxT Steerable Introducer; Abbott) was used as an ablation catheter sheath. For mapping, a 20-pole ring catheter (electrophysiology catheters, Inquiry™ and Optima™; Abbott) or an HD Grid catheter (Advisor™ HD Grid Mapping Catheter, Sensor Enabled™ or Bi-D High-Density Mapping Catheter, Sensor Enabled™; Abbott) with an 8.5-F sheath (Swartz™ Braided Transseptal Guiding Introducers SL™ Series; Abbott) was applied. A temperature probe (SensiTherm™, Abbott) was inserted into the esophagus for the real-time monitoring of esophageal temperature. A 10-pole catheter was used in the coronary sinus (CS), and a 10- or 20-pole catheter was utilized in the right ventricle. Transseptal puncture was performed under intracardiac echocardiography guidance. A 20-pole ring catheter or an HD Grid catheter was inserted into the PV during the application of radiofrequency current, and an esophageal catheter and a CS 10-pole catheter were used for annotation. Mapping of the left atrium (LA) was performed during CS pacing (500–600 msec). We performed cardioversion to restore sinus rhythm in patients with continuous AF. However, if the sinus rhythm could not be restored after cardioversion or if AF recurrence was observed immediately after cardioversion, LA mapping was performed during AF.

All patients were anesthetized using a laryngeal mask (i-gel), and their bispectral index was monitored (range: < 60) during the procedure. Dexmedetomidine and propofol were used to achieve deep sedation with controlled ventilation.

The ablation line was prepared using the extended PVI approach; however, more lines were added if considered fit by the operator. The following lines were added based on the operator's discretion: roof, bottom, posterior, anterior, cavotricuspid isthmus, mitral valve isthmus, and superior vena cava (SVC) lines. All radiofrequency applications were performed in a power-control mode, and the upper-temperature limit was set at 45°C. The radiofrequency application was interrupted if the esophageal temperature reached 39°C and was resumed if the temperature dropped to 37°C. If there was a sudden spike in impedance or steam pops were observed, radiofrequency application was discontinued, and the site or method of catheter application was changed.

PVI was assessed using a 20-pole ring catheter or HD Grid catheter during CS pacing, and 10-V pacing was conducted from each PV segment using an ablation catheter to confirm bidirectional block. After the disappearance of the PV potential, a 10-min waiting period was observed. If remnant conduction and early reconnections were observed after the initial ablation, the conduction sites were reassessed using an ablation catheter, 20-pole ring catheter, or HD Grid catheter. Subsequently, additional radiofrequency applications were delivered at the conduction site, and the sites were reevaluated. Additional radiofrequency applications were performed via CP-CD ablation.

Based on a previous report, the bilateral PVs were divided into six segments: anterior and posterior, upper and lower roof, bottom, and carina [16]. In each segment, the areas that required additional radiofrequency applications due to residual PV conduction were examined. Moreover, the most effective application method for each segment was examined. In both methods, PVI was performed under lesion size index (LSI) guidance. Patients with common PVs were excluded because of difficulties in domain segmentation.

Only the radiofrequency applications for PVI were considered; therefore, the applications for cavotricuspid isthmus, mitral valve isthmus, SVC, anterior, posterior, roof, and bottom isolations were excluded. The CP-CD and HP-SD ablation protocols are described below.

Table 1: Ablation methods between conventional-power, conventional-duration ablation and high-power, short-duration ablation

	CP-CD ablation	HP-SD ablation
Output, Watt	25–35	50
Irrigation flow, ml/min	17–30	30
Target contact force, g	10–20	10–20
Maximum duration, second	30	15
Target LSI	4.5	4.5
Auto mark away time, second	3	3
Minimum auto mark time, second	3	3
Auto mark spacing, mm	3	3
Ablation tag diameter, mm	4	6
Target inter-lesion distance, mm	4	6

Comparison of method, power, irrigation flow, target contact force, LSI and inter-lesion distance, and application duration.
CP-CD, conventional-power conventional-duration; HP-SD, high-power short-duration; LSI, lesion size index

Table 2: Baseline characteristics

	CP-CD ablation	HP-SD ablation	p value
N	100	100	
Age, years	68.0 ± 8.8	66.5 ± 10.3	0.26
Male sex, n (%)	75 (75.0)	71 (71.0)	0.63
BMI, kg/m²	23.5 ± 4.1	24.7 ± 3.5	<0.05
LVEF, %	58.8 ± 9.7	59.6 ± 9.8	0.60
LAD, mm	40.0 ± 6.3	39.3 ± 6.0	0.44
LAVI, ml/m²	39.9 ± 14.3	39.6 ± 12.7	0.90
Paroxysmal AF, n (%)	55 (55.0)	60 (60.0)	0.57
AF history, day	818.5 ± 1734.9	701.6 ± 1440.8	0.60
Hypertension, n (%)	50 (50.0)	57 (57.0)	0.40
Diabetes mellitus, n (%)	13 (13.0)	13 (13.0)	1.00
$CHADS_2$ Score	1.5 ± 1.2	1.4 ± 1.1	0.62

Values were presented as mean ± SD, n/n (%), or n.
CP-CD, conventional-power conventional-duration; HP-SD, high-power short-duration; BMI, body mass index; LVEF, left ventricular ejection fraction; LAD, left atrial dimension; LAVI, left atrial volume index; AF, atrial fibrillation; CHADS2, congestive heart failure, hypertension, age, diabetes, stroke

Informed consent was obtained from each patient, and the study protocol was approved by the Ethics Committee of Showa University Fujigaoka Hospital, Japan.

CP-CD ablation protocol

For saline irrigation, CP-CD was set at 17–30 mL/min. In the CP-CD group (control), all applications were performed at 25–35 W. The power output was decreased in areas where the esophageal temperature increased. The target inter-lesion distance was set at 4 mm based on the EnSite-PrecisionTM cardiac mapping system (Abbott) 3D graphic image, and the target force was set at 10–20 g. The current was applied at a maximum of 30 s, and the target was to achieve an LSI of ≥4.5 at the end of the current application (Table 1).

HP-SD ablation protocol

For saline irrigation, HP-SD was set at 30 mL/min. All applications were performed at 50 W. The target inter-lesion distance was set at 6 mm with the same method used in CP-CD ablation, and the target force was set at 10–20 g. The current was applied for 10 s (at a maximum of 15 s), and the target was to achieve an LSI of ≥4.5 at the end of the current application. If there was a sudden increase in the impedance or steam pop was observed, ablation was interrupted (Table 1).

We used a 20-pole ring catheter as the mapping catheter for the first 40 patients in the CP-CD group; subsequently, 160 patients have used HD grid catheters.

Statistical analyses

Variables were presented as mean ± standard deviation or number (percentage), as appropriate. Continuous and categorical data were compared using the Student's t-test and the χ^2 test, respectively (or the Fisher's exact test in case of a small sample). A p value of < 0.05 was considered statistically significant. The time from catheter ablation to AF recurrence was described using the Kaplan–Meier curves and compared with the log-rank test. The JMP software program (version 15.0; SAS, Cary, NC, the USA) was used for analysis.

Results

There were four operators in total, and no particular operator performed only one particular method. In same period 223 consecutive patient were enrolled, the first half of consecutive patients (n = 106) underwent CP-CD ablation, and the second half of consecutive patients (n = 117) underwent HP-SD ablation. Finally, 200 patients were analyzed after excluding those who had common PVs (n = 21), did not undergo contact force-sensing ablation (n = 1), or could not be followed-up (n = 1). Table 2 shows the baseline characteristics of the patients. There were no significant differences in terms of age, sex, body mass index, left ventricular ejection fraction, left atrial dimension, left atrial volume index, prevalence of paroxysmal AF, history of AF, hypertension, and diabetes, or CHADS2 score between the CP-CD and HP-SD groups.

Table 3 presents procedural data. The CP-CD group had a significantly longer procedure time, fluoroscopy time, and average radiofrequency application time and greater number of radiofrequency applications and contact force than the HP-SD group. There were no significant differences in terms of total radiation dose, final success rate, LSI, and incidence rate of complications between the CP-CD and HP-SD groups. One case of cardiac tamponade in the CP-CD group was a complication related to septal puncture and not related to ablation. There were three cases of cerebral infarction in the CP-CD group and two cases in the HP-SD group; also, there was one case of thrombotic cerebral infarction with residual disability in the CP-CD group. However, all the other cases had only minor neurological symptoms that required no special treatment, and had no residual

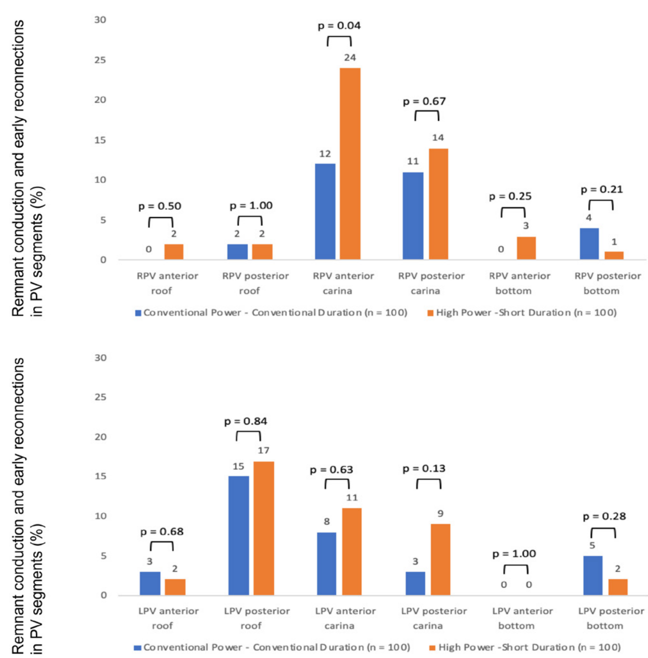

Figure 2: Remnant conduction and early reconnection sites in the CP-CD and HP-SD groups. The upper figure shows the remnant conduction and early reconnections in each region of the right pulmonary vein, and the lower figure depicts remnant conduction and early reconnections in the left pulmonary vein. Values were expressed as n/N (%). PV: pulmonary vein, HP-SD: high-power, short-duration, CP-CD: conventional-power, conventional-duration

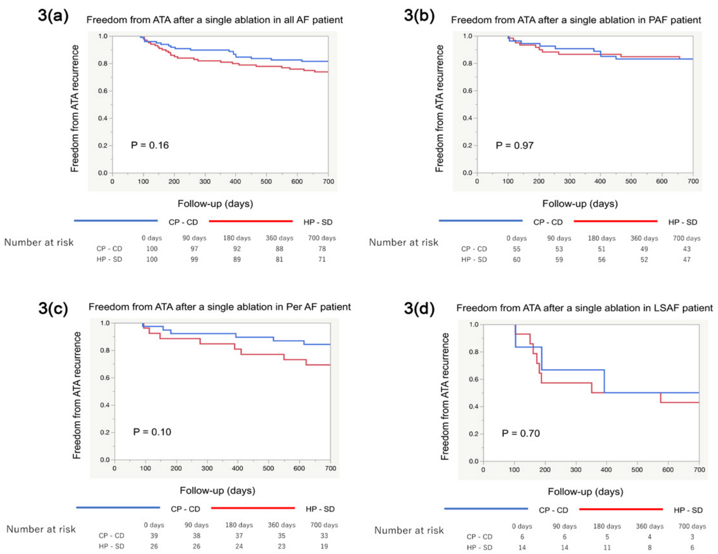

Figure 3: (a) Freedom from ATA after single RFA in all patients. Kaplan–Meier curves showing the rates of freedom from AF and AT/AFL after the initial 3-month blanking period without any antiarrhythmic drugs in the CP-CD and HP-SD groups. (b) Freedom from ATA after single RFA in patients with PAF. Kaplan–Meier curves showing the rates of freedom from AF and AT/AFL after the initial 3-month blanking period without any antiarrhythmic drugs in both groups. (c) Freedom from ATA after single RFA in patients with Per AF. Kaplan–Meier curves showing the rates of freedom from AF and AT/AFL after the initial 3-month blanking period without any antiarrhythmic drugs in both groups. (d) Freedom from ATA after single RFA in patients with LSAF. Kaplan–Meier curves showing the rates of freedom from AF and AT/AFL after the initial 3-month blanking period without any antiarrhythmic drugs in both groups.

ATA: atrial tachyarrhythmia, PAF: paroxysmal atrial fibrillation, Per AF: persistent atrial fibrillation, LSAF: longstanding atrial fibrillation, RFA: radiofrequency ablation, AF: atrial fibrillation, AT: atrial tachycardia, AFL: atrial flutter, HP-SD: high-power, short-duration, CP-CD: conventional-power, conventional-duration

disability.

The two groups were similar in terms of the frequency of additional lines. However, the addition of the SVC line was more frequent in the CP-CD group than in the HP-SD group. Meanwhile, the HP-SD group commonly required the addition of roof and bottom lines.

After the waiting period of post-PV potential disappearance in all 12 PV segments, there was a high rate of remnant conduction and early reconnections in the right PV anterior carina, right PV posterior carina, and left PV posterior roof regions irrespective of the radiofrequency application method (Fig. 2). In the right PV anterior carina, the CP-CD group had a significantly lower rate of remnant conduction and early reconnections after the initial ablation than the HP-SD group (12% vs. 24%, P = 0.04). Figure 3 shows the results of the Kaplan–Meier survival analysis of the cumulative recurrence-free rate after a single ablation in all patients with AF (A), paroxysmal AF (B), persistent AF (C), and longstanding AF (D) who were not on antiarrhythmic drugs. There was no significant difference in terms of the recurrence rates of any type of AF between the HP-SD and CP-CD groups.

Discussion

According to the findings of this study, the HP-SD ablation had a shorter procedure time, fluoroscopy time, total radiation dose than the CP-CD ablation, and both techniques had a similar complications rate. However, remnant conduction and early reconnections were more frequently encountered on the right PV anterior carina in the HP-SD group than in the CP-CD group. There was no significant difference in the cumulative recurrence rate of AF between the two groups.

Preclinical studies may validate the results of this study. In a previous preclinical study performed in a myocardial phantom made using an agar powder substitute, the lesion width was comparable between the HP-SD and CP-CD groups (5.4 vs. 5.2 mm). Meanwhile, the lesion depth was shallower in the HP-SD group than in the CP-CD group [13] (2.2 vs. 2.7 mm). Similarly, in another preclinical study using an in silico model and a porcine ex vivo model, the HP-SD group had a significantly larger lesion diameter than the CP-CD group (7.5 ± 0.6 vs. 8.9 ± 0.4 mm, $p < 0.01$). However, the HP-SD group had a significantly smaller lesion depth than the CP-CD group (5.7 ± 0.6 vs. 4.7 ± 0.6 mm, $p < 0.01$) [17]. Thus, the HP-SD ablation may not be sufficient if the myocardial wall is thick. In an anatomical study on 34 dissected human hearts, the septal region had the greatest mean left atrial wall thickness, followed by the anterior wall, posterior wall, and roof (2.2 ± 0.82, 1.86 ± 0.59, 1.4 ± 0.46, and 1.06 ± 0.49 mm, respectively; $p < 0.05$) [15]. The septum may require a longer current application time, which can be the underlying reason for the significant number of right PV anterior carina reconnections in our study.

Recently, PVI with very HP-SD (90 W, 4 seconds) ablation using

Table 3: Procedural and follow-up details in all participants

	CP-CD ablation	HP-SD ablation	p value
N	100	100	
Procedure time, min	182.6 ± 60.5	136.0 ± 47.3	< 0.0001
Fluoroscopy time, min	63.2 ± 20.8	48.0 ± 17.3	< 0.0001
Exposure dose, Gly	401.5 ± 256.0	377.5 ± 277.0	0.53
No. of application	150.6 ± 39.7	65.7 ± 14.5	< 0.0001
Average RF application time, seconds	13.3 ± 2.7	9.9 ± 0.9	< 0.0001
Contact force, g	15.9 ± 2.7	12.0 ± 2.8	< 0.0001
Watt	30.6 ± 1.1	46.7 ± 0.9	< 0.0001
LSI	4.8 ± 0.3	4.9 ± 0.4	0.74
Successful PVI	97 (97)	100 (100)	0.25
Additional line	72 (72.0)	60 (60.0)	0.10
roof and bottom line	8 (8.0)	23 (23.0)	< 0.05
Anterior line	1 (1.0)	2 (2.0)	1.00
Mitral isthmus	8 (8.0)	8 (8.0)	1.00
CTI	59 (59.0)	51 (51.0)	0.32
SVC	9 (9.0)	0	<0.005
Complication	4 (4.0)	2 (2.0)	0.44
Cerebral infarction	3 (3.0)	2 (2.0)	0.68
Tamponade	1 (1.0)	0	1.00
Atrioesophageal fistula	0	0	1.00

Values are n/N (%), mean ± SD, or mean (median; range)
Procedure time was from the local anesthesia to sheath removal.
CP-CD, conventional-power conventional-duration; HP-SD, high-power short-duration; PVI, pulmonary vein isolation; RF, radio frequency; LSI, lesion size index; CTI, cavotricuspid isthmus line; SVC, superior vena cava

a novel QDOT MICRO (Biosense Webster, Inc., Irvine, California) catheter set at over 50 W has been reported. A previous clinical study using this catheter for very HP-SD ablation showed a similarly low fluoroscopy time and an even lower procedure time [18]. Another study using a QDOT MICRO catheter for CP-CD ablation showed a similarly low fluoroscopy time and an even lower procedure time [19]. Therefore, it may be possible to obtain better results by combining CP-CD and very HP-SD based on the PV segment.

In a clinical setting, late gadolinium-enhanced cardiac magnetic resonance imaging (LGE-CMRI) is one of the best tools for assessing scars created by catheter ablation. A clinical study used LGE-CMRI at 3 months postablation in 70 consecutive patients with AF. Results showed that the CMR-based scar group had a significantly greater ablation time and force-time integral than the nonscar group. Meanwhile, the mean contact force, change in catheter tip temperature, and impedance did not significantly differ between two groups [20]. Thus, the duration of radiofrequency current application matters more than the impedance or contact force. The minimum ablation times to create durable scar lesions were 17.6, 13.6, and 11.0 s at 25, 35, and 50 W, respectively [20]. In HP-SD ablation, the current application time is set at an upper limit of 15 s. If it is beyond 15 s, it can be associated with a risk of steam pop, a limitation of the HP-SD ablation [13]. Meanwhile, in CP-CD ablation, the current application time can be set at a higher limit (upper limit of 60 s), which may be more suitable for thicker walls, such as the septal side of the anterior wall. In addition, other studies have reported that the HP-SD group requires more additional applications on the right PV carina segment than the CP-CD group [21]. Using the HP-SD ablation, an additional application at the carinal line, a more proximal location of the ablation line, or its use in combination with CP-CD ablation in the right PV anterior carina may further reduce the possibility of right PV reconnections; however, further studies should be conducted to elucidate the ideal approach.

In previous reports, esophagus-related complications in HP-SD ablation did not differ from those in CP-CD ablation [22,23]. In this study, there was no significant difference in esophagus-related complications, and no significant difference was observed in remnant conduction and early reconnections in the anterior esophagus (LPV posterior bottom segment).

This study used a steerable sheath in both groups for the highest possible stability. Improving catheter stability using steerable sheaths reduces PV reconduction, thereby decreasing the fluoroscopy time and improving acute and chronic outcomes [24,16]. The high stability and a similar LSI obtained in our study may reflect the main difference in the ablation method compared with a previous study. The procedure time of HP-SD ablation was shorter than that of CP-CD ablation by approximately 45 min, even though reapplication may be required in certain regions occasionally. Shin et al. recently utilized the CP-CD ablation for the posterior and posteroinferior lines and the HP-SD ablation for other areas. Their results suggested that the HP-SD ablation had a lower procedure time than the conventional method [25]. Therefore, the CP-CD ablation might be an appropriate procedure for treating the right PV anterior carina segment. Therefore, this study partially explains one of the limitations associated with HP-SD ablation.

Limitations

The current study had several limitations that should be recognized. First, this was a single-center retrospective serial study, not randomized. Second, in the current study, longer continuous ECG monitoring was not performed. Only 24-hour Holter ECG was performed to confirm recurrence. Hence, a longer ECG monitoring could have detected potential recurrences. Furthermore, additional lines were performed based on the operator's discretion. Therefore, it is difficult to rule out differences in outcomes between the two approaches in a relatively small series of patients. Third, in the HPSD group, the ILD was set at 6 mm, 1.5 times ILD of the CPCD group, which may have resulted in a higher number of the remnant conduction and early reconnections. To accurately compare the two groups, we should set to the same ILD, but based on in vitro reports [26], we set the longer ILD in the HPSD ablation.

However, there was no significant difference in the remnant conduction and early reconnections except in the right PV anterior carina segment, suggesting that LSI 4.5 for HP-SD ablation is less reliable than LSI 4.5 for CP-CD ablation in terms of a depth.

Finally, in this study, adenosine triphosphate (ATP) was not administered to confirm dormant conduction after PVI, and only a 10-min waiting period was used. There are some reports on the evaluation and usefulness of ATP and on a longer waiting time for dormant conduction [6,27,10]. However, the results of a previous study did not show that ATP was beneficial [26], and we performed PVI without ATP. Therefore, dormant conduction was mot conducted using ATP. Nevertheless, a longer waiting time and ATP could have been used to more accurately evaluate remnant conduction and early reconnections.

Conclusion

Compared with CP-CD ablation, HP-SD ablation is associated with a significantly reduced procedure time, and the two techniques have a comparable recurrence rate in the chronic phase. However, LSI-guided CP-CD ablation may be more suitable for managing the right PV anterior carina segment than the HP-SD ablation. Therefore, it may be considered desirable to combined the HP-SD and CP-CD ablation.

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Conflict of Interest

° All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

° This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

° The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript

° The following authors have affiliations with organizations with direct or indirect financial interest in the subject matter discussed in the manuscript:

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