



Risks and Benefits of an Open Irrigation Tip Catheter in Intensive Radiofrequency Catheter Ablation in Patients With Non-Paroxysmal Atrial Fibrillation

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Background: Although open irrigation tip catheters (OITC) are effective in producing transmural radiofrequency (RF) lesions, they have the potential for fluid overload or excessive tissue damage.

Methods and Results: The 203 patients with non-paroxysmal atrial fibrillation (NPAF; 85.2% males, 55.2±10.6 years old) who underwent RF catheter ablation (RFCA) were analyzed retrospectively. Clinical outcomes and complications were compared between RFCA using OITC (n=92) and that using conventional catheters (CONC; n=111). Both the total procedure time (P<0.01) and fluoroscopic time (P<0.001) were shorter in the OITC group than in the CONC group. Total fluid loading during RFCA with OITC was 3.2±0.9L, and the average body weight increase was 1.8±1.2 kg. Symptomatic pulmonary edema and/or pleural effusion occurred in 3.3% of patients who had a bigger left atrium (P=0.005), longer duration of ablation procedure (P=0.002), higher post-RFCA serum pro-ANP level (P<0.001), and longer hospitalization (P<0.01).

Conclusions: RFCA for NPAF using OITC results in a shorter procedure time compared with CONC. However, patients with a large left atrium and a large amount of fluid (>4L) infused via the OITC need to be carefully monitored to prevent pulmonary edema or pleural effusion because of fluid overload. (*Circ J* 2010; **74**: 644–649)

Key Words: Atrial fibrillation; Catheter ablation; Irrigation tip catheter

It is known that appropriate rhythm control with antiarrhythmic drugs or radiofrequency catheter ablation (RFCA) may improve survival and is superior to the rate control strategy in patients with atrial fibrillation (AF).^{1,2} RFCA of AF is an accepted, effective rhythm control strategy for maintaining sinus rhythm and is less invasive than the maze operation.³ According to the ACC/AHA/ESC guidelines, RFCA is recommended as a second-line therapy in patients with AF that is resistant to flecainide, propafenone or sotalol.⁴ However, AF frequently recurs despite the antiarrhythmic drugs^{1,5} and even after RFCA.^{2,6} The rate of recurrence of non-paroxysmal AF (NPAF), including persistent or permanent AF after successful catheter ablation, is much higher than that of paroxysmal AF;^{7–9} that is, commonly performed ablation techniques, such as bi-atrial circumferential ablation with electrical isolation of the pulmonary veins (PV), are not sufficient for controlling NPAF. Two new technologies have been developed in order to obtain more promising clinical results after AF ablation: (1) 3-dimensional (3D) electroanatomical mapping system that guides linear ablation without a conduction gap, ensuring a bidirectional

block, and (2) open irrigation tip catheter (OITC), which makes creating a transmural lesion more efficient and safer compared with conventional catheters (CONC).¹⁰ However, OITC carries the risk of fluid overload in patients who require multiple linear ablations of long duration, because continuous saline infusion is required during such ablations. We hypothesized that using the OITC is more efficient and results in better clinical outcomes with minimal adverse events than does CONC for NPAF ablation, so the purpose of this study was to compare OITC and CONC in terms of efficiency, clinical outcome, and adverse events in patients who underwent RFCA of NPAF.

Methods

Study Subjects

From May 2000 to October 2008, 203 consecutive patients who underwent RFCA for NPAF were analyzed retrospectively [173 men (85.2%), 30 women; mean age, 55.2±10.6 years (range, 17–81 years)]. The mean left atrial (LA) size (measured in the parasternal long-axis view) and left ventricular

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Table 1. Baseline Characteristics of the Study Population				
	All (n=203)	CONC (n=111)	OITC (n=92)	P value
Age (years)	55.18±10.61	53.67±11.60	57.01±9.00	0.25
Male	173 (85.2%)	96 (86.5%)	77 (83.7%)	0.58
Chronic long-standing AF	46 (22.7%)	10 (9.0%)	36 (39.1%)	<0.01
Other arrhythmias				<0.01
Atrial flutter	26 (12.8%)	4 (3.6%)	22 (23.9%)	
Sick sinus syndrome	6 (3.0%)	4 (3.6%)	2 (2.2%)	
Hypertension	23 (11.3%)	3 (2.7%)	20 (21.7%)	<0.01
Diabetes mellitus	4 (2.0%)	0 (0%)	4 (4.3%)	0.04
Thyroid disease	3 (1.5%)	0 (0%)	3 (1.5%)	0.09
Cerebral vascular accident	6 (3.0%)	0 (0%)	6 (3.0%)	0.08
Coronary heart disease	4 (2.0%)	0 (0%)	4 (4.3%)	0.04
History of CHF	17 (8.4%)	9 (8.1%)	8 (8.7%)	0.88
Valvular heart disease	17 (8.4%)	6 (5.4%)	11 (12.0%)	0.93
Non-ischemic cardiomyopathy	5 (2.5%)	3 (2.7%)	2 (2.2%)	0.81
LA (AP diameter, mm)	45.10±5.83	43.47±4.99	46.50±6.16	0.01
LVEF (%)	51.71±8.43	50.89±8.60	52.41±8.27	0.24
Anti-arrhythmic medications				0.23
Class Ic	47 (23.2%)	21 (18.9%)	26 (28.3%)	
Class III	52 (25.6%)	28 (25.2%)	24 (26.1%)	

CONC, conventional catheter; OITC, open irrigation tip catheter; AF, atrial fibrillation; CHF, congestive heart failure; LA, left atrium; AP, anteroposterior; LVEF, left ventricular ejection fraction.

ejection fraction were 45.1 ± 5.8 mm and $51.7\pm 8.4\%$, respectively. Some patients (20.7%) had comorbid heart disease, such as coronary artery disease, mild degree of valvular heart disease, non-ischemic cardiomyopathy, or a history of congestive heart failure. The exclusion criteria were: (1) permanent AF refractory to electrical cardioversion; (2) LA >55 mm; and (3) associated rheumatic valvular heart disease with moderate to severe valvular dysfunction. All anti-arrhythmic medications were discontinued for a period corresponding to at least 5 half-lives to determine the pure effect of catheter ablation of AF; 52 patients (25.6%) were taking amiodarone, which was discontinued for at least 4 weeks prior to the procedure. Anticoagulation therapy was maintained for a target INR >2.0 at least 4 weeks before the procedure. Transesophageal echocardiography was performed to exclude an LA thrombus on the day of or the day before the procedure. 3D spiral computed tomography (CT; 64 Channel, Light Speed Volume CT, Philips, Brilliance, The Netherlands) images were obtained for all patients to visually define the anatomy of the LA and PV for further 3D electroanatomical mapping.

Electrophysiological Mapping Procedure

The study protocol was approved by the Institutional Review Board of Anam Hospital of Korea University. All patients provided informed written consent. The high right atrium (RA), low RA, and coronary sinus (CS) were mapped with a decapolar catheter (Bard Electrophysiology Inc, Lowell, MA, USA) and duo-decapolar catheter (St Jude Medical Inc, Minnetonka, MN, USA) inserted via the left femoral vein. A quadripolar catheter was also placed in the superior vena cava (SVC). Intracardiac electrograms were recorded using a Prucka CardioLab™ electrophysiology system (General Electric Health Care System Inc, Milwaukee, WI, USA). Double trans-septal punctures were performed, and multi-view pulmonary venograms were obtained. After trans-septal access was obtained, systemic anticoagulation was achieved with intravenous heparin to maintain an activated clotting

time of 350–400 s. For electroanatomical mapping, the 3D geometry of both the LA and PV was generated using the NavX system (St Jude Medical) and then merged with the 3D spiral CT images.¹¹ To avoid inadvertent collateral injury, the esophagus was visualized by barium swallow and displayed on the monitor during the ablation procedure.

RFCA

We used a conventional 5 mm tip catheter (n=111; 35 W, 55°C) in 54.7% of the patients (111/203; CONC group) and an open irrigation 3.5-mm-tip deflectable catheter (Celsius, Johnson & Johnson, Inc; Diamond Bar, CA, USA; irrigation flow rate 20–30 ml/min; 30 W; 47°C) in 45.3% (92/203; OITC group) to deliver RF energy for ablation (Stockert generator, Biosense Webster Inc; Diamond Bar, CA, USA). We used the CONC between the years 2000 and 2006, and the OITC between 2006 and 2008. To overcome the selection bias of this non-randomized retrospective study, we included patients who were mapped with the same 3D mapping technique, and ablated with a similar ablation method described as follows. We also excluded patients who underwent ablation with an aberrant technique, such as epicardial ablation. All patients initially underwent circumferential antral ablation with electrical PV isolation (PVI). Following antral ablation in the NPAF patients, we generated an LA roof line, a left lateral isthmus line, and a cavotricuspid isthmus (CTI) line and confirmed the bidirectional block by differential pacing.¹² Additional ablations were performed inside the CS if bidirectional block of the left lateral isthmus was not achieved by endocardial ablation alone. In selected patients who required substrate modification, antero-septal and anterolateral lines were generated at the anterior LA. In patients with residual fibrillatory response after linear ablation, we performed complex fractionated atrial electrogram (CFAE) mapping¹³ and ablated the areas of CFAE.¹⁴ The endpoint of NPAF ablation was no immediate recurrence of AF after cardioversion during isoproterenol infusion (5–10 µg/min). In patients

Table 2. Comparison of Procedures Using a CONC or an OITC

	CONC	OITC	P value
Procedure time (min)	312.8±99.4	283.8±69.3	<0.01
Fluoroscopic time (min)	102.5±43.9	83.6±29.3	<0.001

Abbreviations see in Table 1.

who underwent RFCA with the OITC, furosemide (20mg) was injected when more than 3L of saline was infused during the procedure. The patient's body weight was checked for at least 2 days after the RFCA procedure, and chest radiography and/or echocardiography were performed if there was any complaint of shortness of breath.

Biochemical Analysis of Plasma Pro-Atrial Natriuretic Peptide

We measured the pre- and 24-h post-RFCA plasma levels of pro-atrial natriuretic peptide (pro-ANP) using ELISA kits (R&D Systems, Minneapolis, MN, USA) to evaluate the degree of fluid overload-induced biochemical changes.

Post-Ablation Management and Follow-up

Warfarin was administered to all patients for at least 3 months after RFCA for a target INR of 2.0–3.0. Patients were asked to visit the outpatient clinic at 1, 3, 6, 9, and 12 months after RFCA and then every 6 months thereafter for follow-up. ECG was performed at every visit or any time the patient reported palpitations. Holter ECG (24- or 48-h) and/or event

recorder was evaluated at 3, 6, and 12 months after RFCA, and then biannually. If any ECG documented an AF episode after the 3-month blanking period during follow-up, the patient was diagnosed as having clinical recurrence and anti-arrhythmic medications were prescribed. Patients were also advised to call a clinician or visit the outpatient clinic if they experienced symptoms suggestive of an arrhythmia.

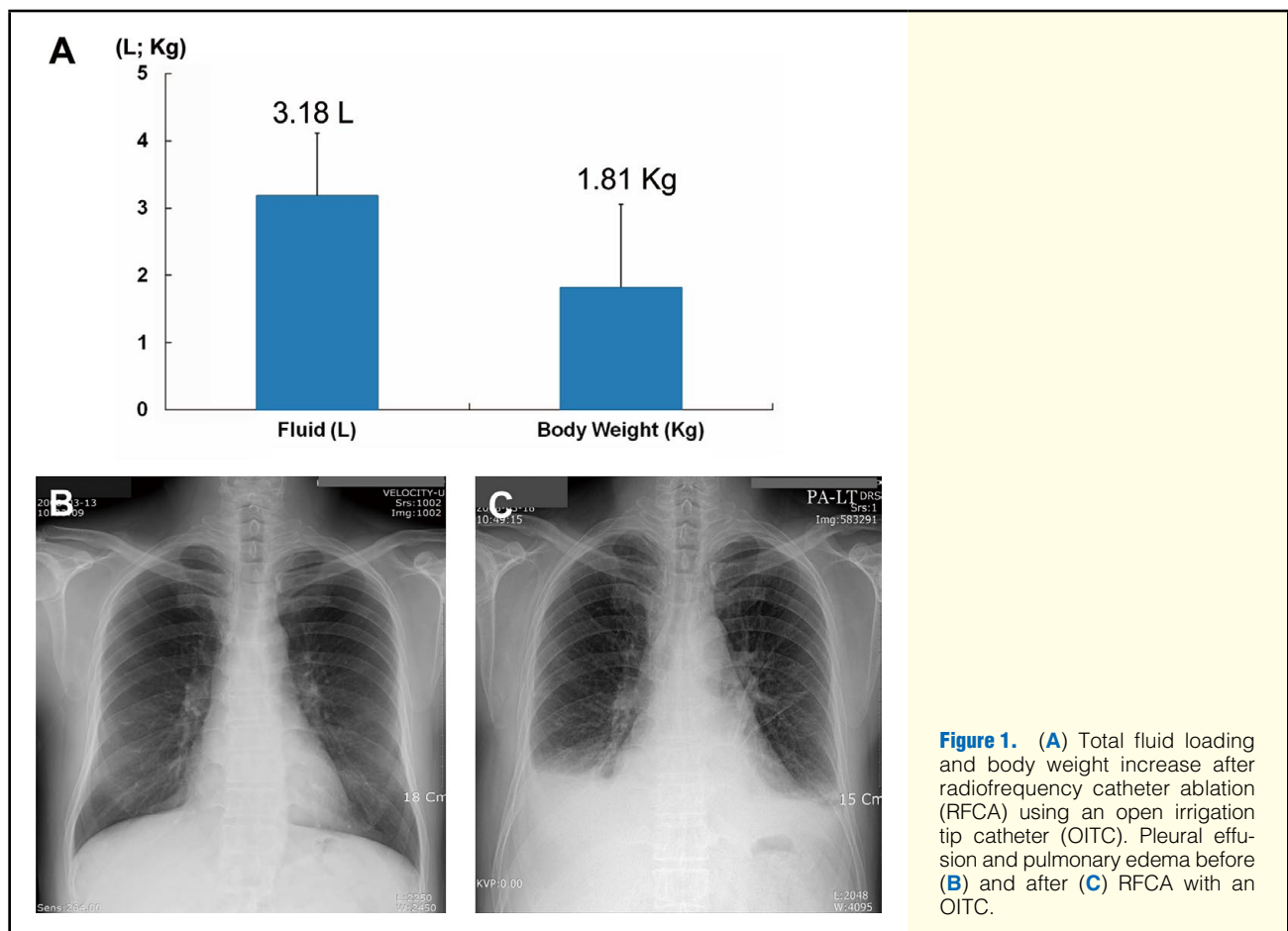
Statistical Analysis

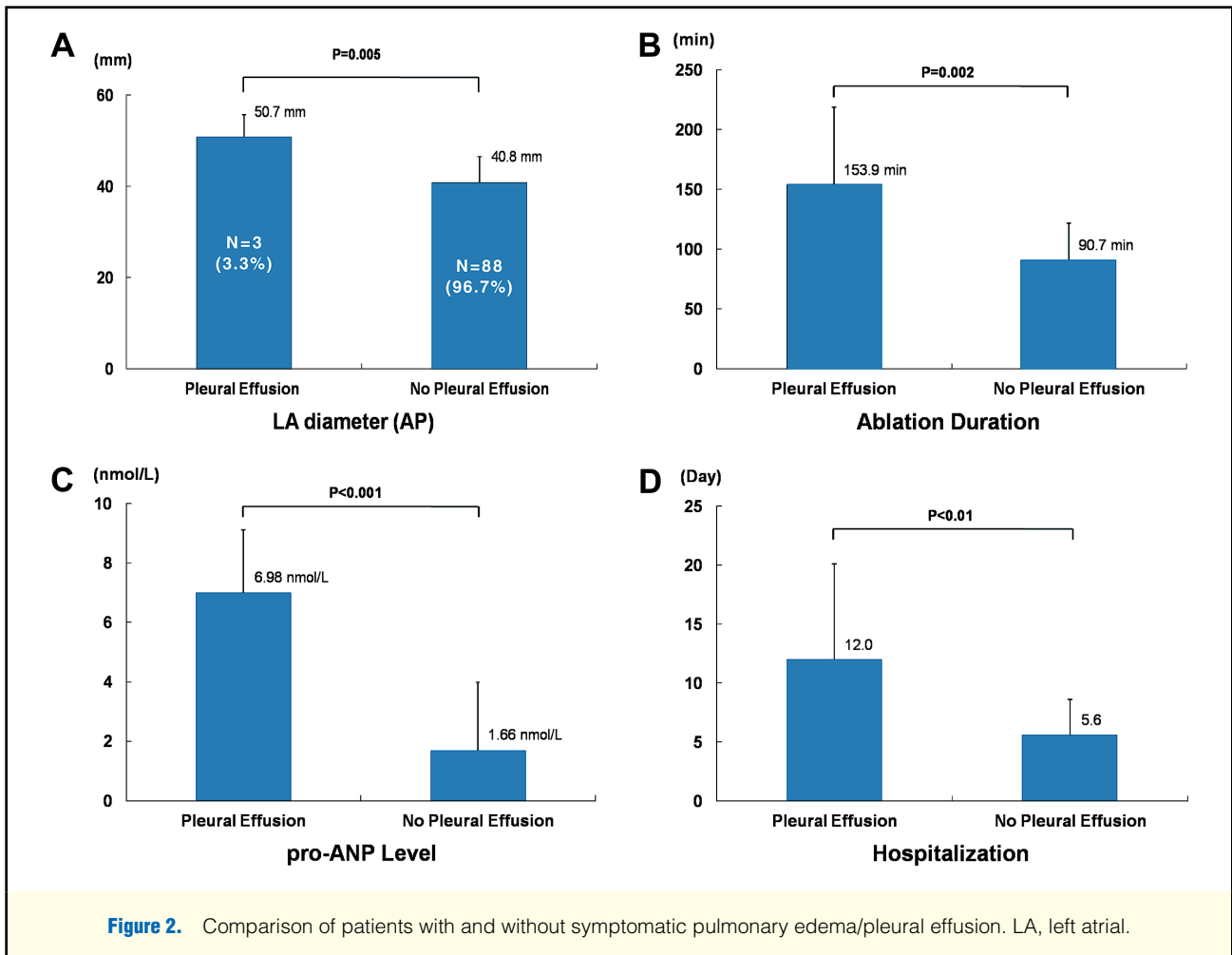
Continuous variables are expressed as mean±SD and were compared by Student's t-test. Categorical variables are presented as frequencies (%) and counts and were compared by chi-square analysis or with the Fisher exact test for small numbers, as appropriate. All tests were 2-tailed, with statistical significance set at $P<0.05$. Statistical tests were performed using SPSS version 15 (SPSS Inc, Chicago, IL, USA).

Results

Patients' Characteristics

The baseline characteristics of the patients are summarized in **Table 1**. In patients in the OITC group, the proportions of those with chronic long-standing AF, combined atrial flutter/tachycardia, hypertension or coronary artery disease were higher than in the CONC group. Also, the anteroposterior diameter of LA was longer in the OITC group than in the CONC group. Of the patients with NPAF, bi-atrial ablation with circumferential PVI was achieved in 100% without exception. Linear ablation was performed at the CTI in 90%,





LA roof in 60%, left lateral isthmus in 59.4%, left-side septum 34%, posterior inferior LA in 5.9%, and LA anterior wall in 2%. Bidirectional block was tested after linear ablations and confirmed after CTI and roof ablation. We also performed additional ablation at the inside CS in 27%, SVC in 5%, and RA ablation in 8.9% of patients.

Procedure Duration and Related Complications

The total procedure time and fluoroscopic time were significantly shorter in the OITC group than in the CONC group (Table 2). Procedure-related complications developed in 7 of 233 patients (3%): hemopericardium in 4 (2 in OITC vs 2 in CONC), transient ischemic attack in 1 (CONC), ischemic stroke in 1 (CONC), and PV stenosis in 1 patient (CONC). We had 2 cases of hemopericardium during OITC ablation, occurring during left lateral isthmus ablation in 1 patient and caused by inadvertent catheter handling in the other patient. For optimal RF energy delivery, we used 20 W with a flow rate of 17–20 ml/min during posterior LA ablation in front of the esophagus and 30–35 W with 30 ml/min during ablation at the anterior border of the right-side of the antrum or septum. We also generated dense and fine ablation lesions in the patients with a huge dilated LA with low blood flow. The procedure-related complication rate was not statistically different between the OITC group (2.2%; 2/92) and CONC group (4.5%; 5/111, $P=0.037$).

Procedure-Related Fluid Overload Using OITC

The total amount of fluid infused to irrigate the tip of the OITC during RFCA was 3.18 ± 0.93 L, and the average body weight increase was 1.81 ± 1.24 kg in the morning after the procedure (Figure 1A). Among 92 patients who underwent RFCA using the OITC, symptomatic pulmonary edema and/or pleural effusion occurred in 3 (3.3%; Figures 1B, C) who had larger LA diameters (50.7 ± 5.0 mm vs 40.8 ± 5.7 mm, $P=0.005$), longer duration of RF energy delivery (153.9 ± 64.9 min vs 90.7 ± 30.9 min, $P=0.002$), larger amount of fluid infused (4.99 ± 1.52 L vs 3.07 ± 0.79 L, $P<0.001$), higher post-RFCA plasma pro-ANP level (6.98 ± 2.14 nmol/L vs 1.66 ± 2.32 nmol/L, $P<0.001$), and longer hospitalization (12.0 ± 8.1 days vs 5.6 ± 3.0 days, $P<0.01$) than did those without symptomatic fluid overload (Figure 2).

Discussion

In this study, we evaluated the potential adverse events of fluid overload after long-lasting OITC ablation of NPAF. We demonstrated that RFCA of NPAF using the OITC has a better clinical outcome with a shorter procedure time than when using the CONC. However, patients with a large LA and a large amount of fluid (>4 L) infused via the OITC need to be carefully monitored to prevent pulmonary edema or pleural effusion caused by fluid overload.

Using the OITC in AF Ablation

The OITC was developed to deliver RF energy to deep tissue and has been widely used in AF ablation. With the OITC, active cooling of the electrode–tissue interface during RF delivery prevents the temperature rising at the tip–tissue interface and reduces the rise in impedance, thereby enabling longer applications at higher power levels for larger and deeper lesion formation.^{15–17} In addition, the maximal heating point is shifted down into the intramyocardial layers, which increases lesion depth and the diameter of the intramural lesion while the size of the surface lesion remains unchanged.^{15,18,19} Experimental studies have shown that an OITC may produce deeper and larger lesions without carbonization of the tip,^{3,7} so it is useful for generating transmural lesions during linear ablation, especially in thick myocardium such as that of the left ventricle or in areas of low blood flow for cooling. Its use may also improve the AF ablation outcome and potentially reduce the incidence of embolic complications.^{7,18,19} During redo-ablation of AF, conduction recurrence at the PV–LA junction is common, which suggests that RF lesions around the PV were not transmural.^{20,21} Therefore, using the OITC has advantages in AF ablation by shortening the procedure time, reducing PV conduction recurrence, and improving the clinical outcome.^{15,18,22} It has been reported that PVI with the OITC reduces both the symptomatic recurrence of AF and the rate of PV stenosis as compared with standard temperature-controlled ablation using a CONC.²²

Potential Complications During AF Ablation Using the OITC

The introduction of irrigation tip catheters has given rise to a new problem. The depth of the lesions created by standard ablation may theoretically be sufficient to involve the entire thickness of the veno-atrial junction, and deeper injury might increase the risk of cardiac tamponade and damage to neighboring structures.^{23–26} The discrepancy of temperature between the thermosensor and deep tissue is likely to be increased in areas of high blood flow by increasing the irrigation flow rate or by cooling the irrigant.¹⁰ In a canine model, it took approximately 25 s for the peak tissue temperature to reach 80°C using an OITC. Temperatures exceeding 40°C with power greater than 30 W may be associated with greater risk of steam pops and rises in impedance, particularly during long RF applications exceeding 1 min. In contrast, low blood flow in the dilated and poorly contracting atrium of long-lasting NPAF results in poor RF energy delivery with the OITC, and a high flow rate can facilitate RFCA efficacy.^{18,27,28} In patients with NPAF, low electrogram voltage at the scar area is another factor obscuring the determination of efficient RF energy delivery and voltage abatement. In addition, with the remote navigation system, the power and stability of catheter contact differs from that of manual ablation, so the efficiency, safety, and optimal RF power when using the OITC remain to be studied.

Another important disadvantage of the OITC is the potential to deliver a significant fluid load. As a result, pulmonary edema and pleural effusion may develop even in patients with normal left ventricular systolic function. During extensive and long-lasting RF ablation with the OITC, substantial peri-procedural fluid loading should be anticipated, especially in patients with NPAF and heart failure. Appropriate use of diuretics and body weight monitoring is highly recommended in such patients.

Study Limitations

This study had the limitations of a retrospective follow-up analysis. The patients were a highly selected group referred for rhythm control, and their number was also limited.

Conclusion

We evaluated the potential adverse events of fluid overload after long-lasting ablation of NPAF using the OITC. RFCA of NPAF using the OITC results in a shorter procedure time than when using a CONC. However, patients with a large LA and a large amount of infused fluid (>4L) via the OITC need to be carefully monitored to prevent pulmonary edema or pleural effusion caused by fluid overload.

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