Received: 21 July 2018 | Accepted: 28 August 2018

DOI: 10.1002/joa3.12127

ORIGINAL ARTICLE

WILEY Journal of Arrhythmia Open Access

Midterm outcomes of catheter ablation for atrial fibrillation in patients with cardiac tamponade

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Abstract

Background: Cardiac tamponade is a serious complication of catheter ablation for atrial fibrillation (AF). However, the outcomes of catheter ablation in patients of cardiac tamponade are unknown.

Methods: We performed catheter ablation in 2467 sessions of AF or a recurrence of AF between January 2007 and January 2016. Of these, 29 events in 27 patients (1.18%: 22 men; 64.5 ± 10.4 years; 17 with paroxysmal AF) of cardiac tamponade during or after the procedure were recorded. The clinical characteristics and outcomes of these 29 events were studied in detail.

Results: Of the 19 events where the ablation procedure was completed, seven events developed acute recurrence of AF (36.8%). Of the 10 events with an incomplete procedure, 10 exhibited AF recurrence (100.0%). Direct oral anticoagulants were used in seven events, and clinical outcomes were not significantly different compared to the remaining 21 events that were prescribed warfarin. Pericarditis occurred in 10 events (34.5%) after the procedure, and the incidence rate was lower in patients receiving prophylactic nonsteroidal anti-inflammatory drugs or steroids (2/15, 13.3% vs 8/14, 57.1%; $P = 0.013$). Repeated sessions were performed in 12 events (two with a complete initial procedure, 10 with an incomplete initial procedure). Freedom from atrial arrhythmias was observed in 27 events (93.1%, 9 with antiarrhythmic drugs) over midterm follow-up (3.1 ± 2.6 years).

Conclusion: Although cardiac tamponade caused by catheter ablation led to a high rate of acute AF recurrence and pericarditis, the midterm recurrence rates of AF are unaffected if the procedure can be completed.

KEYWORDS

anticoagulants, atrial fibrillation, cardiac tamponade, catheter ablation, pericarditis

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1 | INTRODUCTION

The effectiveness of catheter ablation therapy for atrial fibrillation (AF) is well-established. However, for maximum benefit, a reduction in acute procedure-related complications is essential. In recent years, the number of AF ablation procedures has been increasing worldwide. Correspondingly, the incidence of cardiac tamponade, a serious complication of catheter ablation, is also increasing. However, there is little midterm follow-up research on patients of cardiac tamponade. In a large study, major complications related to AF ablation occurred in 4.54%-6% of patients.[1,2] The mortality rate associated with AF ablation was 0.15%,[2] and cardiac tamponade was the most frequent cause of procedure-related death.[3,4] The incidence rate of cardiac tamponade is approximately 1%-1.31% but subsequent patient outcomes are not clear.[1,2,5] Further, the use of direct oral anticoagulants (DOAC) has recently increased all over the world.[6] The association between this change in anticoagulant therapy and cardiac tamponade is still unclear. In addition, although pericarditis sometimes occurs alongside cardiac tamponade, the relationship between them remains poorly understood. Distinctive cases of delayed cardiac tamponade after AF ablation have also been reported,[7-9]

TABLE 1 Clinical characteristics of 29 cardiac tamponade events

Event no	Patient no	Age (years)	Sex	BMI (kg/m^2)	AF type	LAD (mm)	LV-EF (%)
1	1	63	M	24.7	PAF	37	72
2	2	73	M	21.4	PAF	41	75
3	3	63	M	23.5	PAF	33	60
4	4	74	F	20.5	PAF	39	72
5	5	64	M	23.6	PerAF	41	69
6	6	62	M	25.9	PAF	42	68
7	7	75	F	22.5	PAF	40	68
8	8	64	M	27.7	PAF	43	72
9	9	68	M	27.6	PAF	34	62
10	10	65	M	21.9	LSPerAF	49	62
11	10	65	M	21.9	LSPerAF	49	62
12	11	42	M	28.0	PerAF	36	53
13	12	70	M	22.7	PerAF	42	66
14	13	59	M	16.4	PerAF	51	73
15	14	67	M	24.4	PAF	41	64
16	15	42	M	22.7	PerAF	43	69
17	16	76	M	24.0	PerAF	44	68
18	17	51	F	28.5	PAF	34	66
19	18	49	F	26.9	PerAF	38	71
20	19	65	M	24.5	PerAF	45	63
21	20	61	F	30.2	PAF	39	75
22	21	60	M	21.2	PAF	39	72
23	22	64	M	26.7	LSPerAF	49	72
24	23	73	F	19.1	PAF	37	60
25	24	80	F	22.0	PAF	39	68
26	25	70	M	28.8	PAF	48	70
27	26	66	M	27.3	LSPerAF	42	69
28	27	76	M	23.0	PAF	48	77
29	27	76	M	23.0	PAF	48	77

AF, atrial fibrillation; AR, aortic regurgitation; ASD post ope, atrial septal defect postsurgical operation; BMI, body mass index; Complete, procedure could be completely ended; F, female; HOCM, hypertrophic obstructive cardiomyopathy; M, male; LAD, left atrial diameter; LSPerAF, long-standing persistent AF; LV-EF, left ventricular-ejection fraction; Not use, anticoagulant drug was not used before procedure; Onset, the time that cardiac tamponade occurred; PAF, paroxysmal AF; PerAF, persistent AF; VSA, vasospastic angina.

with rupture of an epicardial hematoma or pericarditis as the postulated causes. The aim of this study was to clarify the clinical characteristics and midterm outcomes of patients with cardiac tamponade.

2 | METHODS

2.1 | Study participants

A total of 2467 sessions in which patients with AF and atrial tachycardia (AT) related to AF ablation, treated with catheter ablation between January 2007 and January 2016, were retrospectively enrolled in this study. All arrhythmias were resistant to at least one antiarrhythmic drug. Of these patients, 29 events (22 males; age, 64.5 ± 10.4 year-old; paroxysmal AF [PAF], 17; Table 1) exhibited cardiac tamponade during or after the procedure (29 events, 1.18% of total cohort). PAF was defined as AF lasting 7 or fewer days, and persistent atrial fibrillation (PerAF) as AF lasting >7 days. Long-standing persistent atrial fibrillation (LSPerAF) was defined as AF persisting for >1 year. The recurrence blanking period was set at 3 months. The clinical characteristics of the 29 events, procedure-related data, acute outcomes, and midterm outcomes were examined

Disease	Anticoagulant drug	Antiplatelet drug	Onset situation	Pericardiocentesis	Drainage blood type	Drainage blood (mL)
—	Warfarin	—	Left atrium	Done	Venous	300
—	Warfarin	—	Left atrium	Done	Arterial	160
—	Warfarin	—	Left atrium	Done	Arterial	175
—	Warfarin	—	Ward	Done	Venous	160
—	Warfarin	Aspirin	Left atrium	Done	Venous	360
—	Warfarin	—	Trans septum	Not performed	—	—
—	Dabigatran	—	Left atrium	Not performed	—	—
—	Warfarin	—	Left atrium	Not performed	—	—
—	Warfarin	—	Left atrium	Done	Venous	500
—	Warfarin	—	Left atrium	Done	Arterial	150
—	Warfarin	—	Left atrium	Done	Arterial	250
—	Warfarin	—	Ward	Done	—	—
ASD post ope	Warfarin	—	Trans septum	Done	Arterial	250
—	Warfarin	—	Left atrium	Done	Venous	500
—	Warfarin	—	Left atrium	Done	Arterial	160
—	Warfarin	—	Trans septum	Not performed	—	—
AR	Warfarin	—	Ward	Done	Venous	200
—	Warfarin	—	Ward	Not performed	—	—
Funnel chest	Warfarin	—	Left atrium	Done	Arterial	1000
—	Warfarin	—	After discharge	Done	Venous	600
—	Dabigatran	—	Left atrium	Done	Venous	100
HOCM	Dabigatran	—	Left atrium	Done	Venous	350
—	Warfarin	—	Post procedure	Not performed	—	—
HOCM	Apixaban	—	Left atrium	Done	Venous	250
—	Not use	—	Left atrium	Done	Not mentioned	1300
—	Warfarin	—	Left atrium	Not performed	—	—
—	Rivaroxaban	—	Left atrium	Done	Venous	300
VSA	Rivaroxaban	Clopidogrel	Left atrium	Done	Venous	1200
VSA	Rivaroxaban	Clopidogrel	After discharge	Done	Not mentioned	300

TABLE 2 Clinical outcome of 29 cardiac tamponade events

Event no	Patient no	Pericardiocentesis	Drainage (days)	Hospital stay (days)	Complete procedure	Procedure	Contact force
1	1	Done	2	6	Yes	PVI, SVC	No
2	2	Done	3	12	No	PVI	Yes
3	3	Done	2	8	Yes	PVI	No
4	4	Done	2	13	Yes	PVI, CTI	No
5	5	Done	2	10	Yes	PVI, roof	No
6	6	Not performed	—	7	No	C.T. occurred before PVI	No
7	7	Not performed	—	10	Yes	PVI	Yes
8	8	Not performed	—	5	No	C.T. occurred before PVI	No
9	9	Done	3	13	Yes	PVI, CTI	No
10	10	Done	2	7	No	PVI	No
11	10	Done	3	4	Yes	PVI	No
12	11	Done	0	9	No	PVI	No
13	12	Done	3	11	Yes	PVI	Yes
14	13	Done	2	40	No	C.T. occurred before PVI	No
15	14	Done	2	12	No	C.T. occurred before PVI	No
16	15	Not performed	—	15	No	C.T. occurred before PVI	No
17	16	Done	2	14	Yes	PVI, CTI	No
18	17	Not performed	—	18	Yes	PVI, SVC, CTI	No
19	18	Done	1	14	Yes	PVI	Yes
20	19	Done	5	10	Yes	PVI, CFAE, roof, CTI	Yes
21	20	Done	2	6	No	PVI, CTI	Yes
22	21	Done	3	7	Yes	PVI, CTI	Yes
23	22	Not performed	—	4	Yes	PVI, roof, CTI	Yes
24	23	Done	0	7	Yes	Cryoballon, CTI	No
25	24	Done	3	22	Yes	PVI	Yes
26	25	Not performed	—	13	No	C.T. occurred before PVI	No
27	26	Done	2	6	Yes	PVI, CTI	Yes
28	27	Done	4	19	Yes	Cryoballon	No
29	27	Done	4	14	Yes	C.T. occurred before PVI	No

AF, atrial fibrillation; AT, atrial tachycardia; CFAE, complex fractionated atrial electrogram; CTI, cavo tricuspid isthmus line ablation; C.T. occurred before PVI, cardiac tamponade occurred before pulmonary vein isolation; LSPerAF, long-standing persistent atrial fibrillation; PAF, paroxysmal atrial fibrillation; PerAF, persistent atrial fibrillation; PVI, pulmonary vein isolation; roof, left atrium roof liner ablation; SVC, superior vena cava; Redo, redo AF/AT ablation session.

in detail. Ethical approval was granted by the institutional review board at Tsukuba University Hospital.

2.2 | Ablation procedure and anticoagulation

Antiarrhythmic drugs were discontinued for at least five half-lives before the procedure, with the exception of amiodarone. Atrial thrombi were checked by transesophageal echocardiography on the day of (or the day before) the procedure. Surface electrocardiography (ECG) and intracardiac electrograms were continuously displayed and stored on a computer-based digital recording system using filter settings of 30-500 Hz during the procedure (CardioLab System; Prucka Engineering, Houston, TX, USA). In conventional radiofrequency catheter ablation (RFCA) cases, through a single transseptal puncture, a 3.5 mm open-irrigated deflectable catheter (ThermoCool; Biosense Webster, Diamond Bar, CA, USA) was used for mapping and ablation. The force-sensing ablation catheter (Smarttouch; Biosense Webster) was used if it was possible in terms of insurance-related concerns. Radiofrequency (RF) energy was delivered at a power of 20-35 W, maximum irrigation rate of 30 mL/min, and maximum temperature of 42°C. The ipsilateral pulmonary vein (PV) was circumferentially ablated under 3D mapping system guidance (CARTO; Biosense Webster; or Ensite Navix; St Jude Medical, St.

Preventive administration	Pericarditis	Acute recurrence	Redo	Midterm AF/AT control	AF type	Drug
Yes	No	No	No	Yes	PAF	—
Yes	No	Yes	Yes	Yes	PAF	Propafenone
Yes	No	No	No	Yes	PAF	—
Yes	No	Yes	No	Yes	PAF	Propafenone
Yes	No	No	No	Yes	PerAF	Bepridil
Yes	No	Yes	Yes	Yes	PAF	—
Yes	No	No	No	Yes	PAF	—
Yes	No	Yes	Yes	Yes	PAF	—
No	No	No	No	Yes	PAF	—
No	No	Yes	Yes	Yes	LSPerAF	Amiodarone
No	No	No	No	Yes	LSPerAF	Amiodarone
Yes	No	Yes	Yes	Yes	PerAF	—
Yes	No	Yes	No	No	PerAF	Amiodarone
No	No	Yes	Yes	No	PerAF	Amiodarone
No	Yes	Yes	Yes	Yes	PAF	—
No	Yes	Yes	Yes	Yes	PerAF	—
No	Yes	Yes	No	Yes	PerAF	Amiodarone
No	Yes	Yes	No	Yes	PAF	—
No	Yes	No	No	Yes	PerAF	—
No	Yes	No	No	Yes	PerAF	—
No	No	Yes	Yes	Yes	PAF	—
Yes	No	Yes	Yes	Yes	PAF	Amiodarone
No	No	Yes	Yes	Yes	LSPerAF	Amiodarone
Yes	No	No	No	Yes	PAF	—
Yes	Yes	Yes	No	Yes	PAF	—
Yes	Yes	Yes	Yes	Yes	PAF	—
No	Yes	No	No	Yes	LSPerAF	Amiodarone
No	Yes	No	No	Yes	PAF	—
Yes	No	No	No	Yes	PAF	—

Paul, MN, USA). In cryoballoon cases, a steerable 15 F sheath (Flexcath®; Medtronic Inc., Minneapolis, MN, USA) was used and flushed continuously with heparinized saline. A mapping catheter (Achieve®; Medtronic Inc.) was advanced into each PV, and PV antrum occlusion was considered. Following angiography, a single 3 min application was performed using a second-generation cryoballoon (28 mm Advance balloon; Medtronic Inc) in each targeted PV. In some cases of PerAF and LSPerAF, a left atrial roof line, superior vena cave isolation, and complex fractionated atrial electrogram ablation were added at the discretion of the operator. If AT occurred after intravenous injection of isoproterenol and/or programmed atrial stimulation and incremental burst pacing from the catheter at the top of the right atrium, it was treated accordingly.

Anticoagulant therapy was prescribed before catheter ablation. The attending physician selected the appropriate anticoagulant drug depending on age and renal function. Anticoagulant drugs were chosen among warfarin or factor Xa inhibitors (apixaban, edoxaban, rivaroxaban) or direct oral thrombin inhibitors (dabigatran etexilate). In the case of warfarin, the target prothrombin time-international normalized ratio (PT-INR) was set to 2.0-3.0 in patients younger than 70 years and 1.6-2.6 in those older than 70 years.[10] All patients underwent catheter ablation without interruption of warfarin or DOAC. Immediately following the transseptal puncture, 5000 units

of intravenous heparin were given and heparinized saline was administered via sustained injection to maintain the activated clotting time at 300-400 s. Atrial blood pressure was monitored continuously from the 4 Fr sheath positioned within the right femoral artery.

2.3 | Definition of arrhythmia, cardiac tamponade, and pericarditis

Atrial arrhythmias were defined as supraventricular arrhythmias related to AF ablation, such as focal or macro-reentrant tachycardia at the left atrium. Common atrial flutter in the right atrium was excluded from this definition in this study. AF or AT related to prior AF ablation was assumed to be sustained for more than 2 h. Cardiac tamponade was defined as an increase in pericardial effusion of >5 mm, a sign of collapse in the atrium or ventricle, and a decrease in systolic blood pressure to <80 mm Hg. Pericarditis was defined by both an increase in pericardial effusion of >5 mm at onset of cardiac tamponade and ST elevation >2 mm on >6 leads.

2.4 | Diagnosis and management of cardiac tamponade

If cardiac tamponade was suspected due to a decrease in blood pressure or unexpected catheter manipulation, the motion of the cardiac silhouette was checked in the left anterior oblique view. Pericardial effusion was confirmed by transthoracic or intracardiac echocardiography. When cardiac tamponade was confirmed, pericardiocentesis was performed under the guidance of fluoroscopy and ultrasonography from the left sternal, apical, or subxiphoid positions. Seven events immediately recovered from hypotensive episodes after transvenous injection of noradrenalin and extracellular fluid; therefore, observational therapy was selected. A pigtail catheter was introduced into the pericardial space and the pericardial fluid was drained. The drained blood was subjected to blood gas analysis to determine the presence of atrial or venous blood. The pericardial fluid was manually drained and connected to a closed drainage system. Heparin and warfarin were neutralized using protamine sulfate and vitamin K. The dabigatran neutralizer was not used in this study and the other DOAC do not have neutralizers, while all patients treated with warfarin received a vitamin K neutralizer. The patients were managed in the intensive care unit while the drainage catheter was within the pericardial space. After pericardial fluid flow stopped, the drainage catheter was removed and oral anticoagulant therapy was resumed.

2.5 | Definition of acute outcome, midterm outcome, AF/AT control, and follow-up

"Acute recurrence" was defined as AF/AT recurrence during the hospital stay for catheter ablation. "Midterm recurrence" was defined as AF/AT recurrence while the patient was being followed in the outpatient clinic or after any required repeat procedures. After discharge, patients were followed at 2 weeks, 1, 3, 6 months, and every 6 months thereafter at an outpatient clinic. Recurrences were investigated according to subjective symptoms, 12-lead ECG, Holter ECG (DSC-3300; Nihon Kohden, Tokyo, Japan), and an event recorder (HCG-901; Omron, Kyoto, Japan). Antiarrhythmic drugs were discontinued after catheter ablation at the discretion of the attending physician with input from the patient. "AF/AT control" was defined as the maintenance of sinus rhythm with or without antiarrhythmic drugs.

2.6 | Statistical analyses

Continuous variables are presented as means ± 1 standard deviation, and skewed variables are expressed as medians with interquartile ranges. Student's *t* test or the Mann-Whitney *U* tests were performed for two-group comparisons of continuous variables, as per

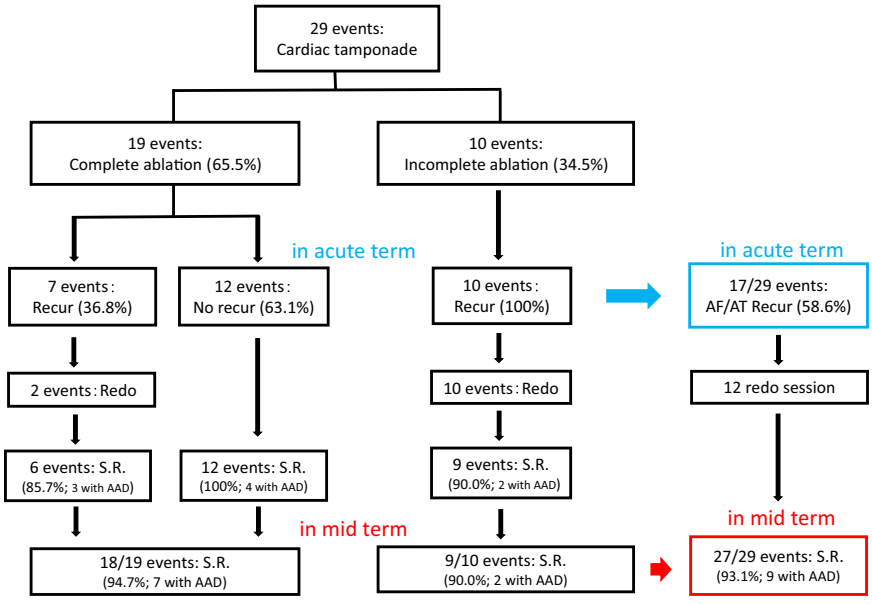


FIGURE 1 The results of the acute and midterm recurrence of catheter ablation in patients with cardiac tamponade. AAD, antiarrhythmic drug; AF, atrial fibrillation; AT, atrial tachycardia; Complete Ablation, procedure was completed; Incomplete Ablation, procedure could not be completed; No recur, AF and AT did not recur; Recur, AF or AT recurred; S.R., sinus rhythm

TABLE 3 Comparison of clinical characteristics between warfarin group and DOAC group

Demographic variables	All events n = 28[a]	Warfarin Group n = 21	DOAC Group n = 7	*P*
Age (y ± SD)	64.4 ± 9.30	62.7 ± 9.44	69.6 ± 7.10	0.088
Male, n	22/28 (78.6%)	18/21 (85.7%)	4/7 (57.1%)	0.111
BMI (kg/m^2)	24.2 ± 3.22	24.4 ± 3.10	23.8 ± 3.76	0.658
PAF, n	16/28 (57.1%)	10/21 (47.6%)	6/7 (85.7%)	0.078
LAD (mm)	41.9 ± 5.08	41.9 ± 5.37	41.9 ± 4.45	1.000
LV-EF (%)	68.1 ± 5.74	67.1 ± 5.39	71.1 ± 6.10	0.108
Onset situations				
EP lab, n	22/28 (78.6%)	16/21 (76.2%)	6/7 (85.7%)	0.595
Ward, n	4/28 (14.3%)	4/21 (19.0%)	0/7 (0.0%)	0.212
Blood type[b]				
Venous blood, n	12/19 (63.2%)	7/14 (50.0%)	5/5 (100%)	0.047*
Atrial blood, n	7/19 (36.8%)	7/14 (50.0%)	0/5 (0.0%)	0.047*
Pericardiocentesis, n	22/28 (78.6%)	16/21 (76.2%)	6/7 (85.7%)	0.595
Hospital stay (days)	11.2 ± 6.94	11.7 ± 7.53	9.9 ± 4.95	0.560
Drainage blood (mL)	363 ± 286 (n = 20)	340 ± 240 (n = 14)	417 ± 393 (n = 6)	0.598
Complete procedure, n	18/28 (64.3%)	12/21 (57.1%)	6/7 (85.7%)	0.172
Preventive administration, n	14/28 (50.0%)	10/21 (47.6%)	4/7 (57.1%)	0.662
Pericarditis, n	9/28 (32.1%)	7/21 (33.3%)	2/7 (28.6%)	0.815
Acute recurrence, n	16/28 (57.1%)	14/21 (66.7%)	2/7 (28.6%)	0.078
Midterm recurrence, n	2/28 (7.1%)	2/21 (9.5%)	0/7 (0.0%)	0.397
Pre CRP (mg/dL)	0.42 ± 1.69	0.09 ± 0.12	1.41 ± 3.35	0.071
Max CRP (mg/dL)	6.71 ± 6.66	6.24 ± 6.47	8.11 ± 7.52	0.530

Acute recurrence, AF/AT recurrence in acute term; AF, atrial fibrillation; AT, atrial tachycardia; BMI, body mass index; Complete procedure, procedure could be completely ended; DOAC, direct oral anticoagulants; EP, electrophysiological; Hospital stay, the length of hospitalization; LAD, left atrial diameter; LV-EF, left ventricular-ejection fraction; Max CRP, the maximum value of serum C-reactive protein; Midterm AF/AT control; AF/AT control in midterm; PAF, paroxysmal atrial fibrillation; Pre CRP, the preoperative serum C-reactive protein; Preventive administration, preventive administration for pericarditis; SD, standard deviation.

[a]The number of the patients who took anticoagulant was 28, as one patient did not take it before catheter ablation.

[b]The number of this event was 19 of 28, as the drainage was not performed in seven, and the drainage blood type could not be evaluated in the remaining two events.

*$P < 0.05$.

the normality of the data distribution. The chi-squared or Fisher's exact test was used for two-group comparisons of categorical variables. Differences were reported as significant if $P < 0.05$. All statistical analyses were performed using SPSS (version 16.0; SPSS Inc., Chicago, IL, USA).

3 | RESULTS

3.1 | Patients' characteristics

This study included 27 patients (29 events; 64.5 ± 10.4 years; 22 men; body mass index, 24.2 ± 3.2 kg/m^2; Table 1) with cardiac tamponade related to AF ablation. The mean left atrial diameter was 41.6 ± 5.0 mm and the mean left ventricular-ejection fraction was 68.1 ± 5.6%. Oral anticoagulant therapy was being administered for at least 1 month before catheter ablation in 26 patients. Structurally normal hearts were observed in 23 patients while one had undergone patch closure of an atrial septum defect, one was diagnosed with mild to moderate aortic regurgitation on echocardiography, and two exhibited hypertrophic obstructive cardiomyopathy (Table 1).

3.2 | Causes of cardiac tamponade

Cardiac tamponade was caused by intracardiac catheter manipulation in 25 events (25/29; 86.2%), atrial septum puncture in three (3/29; 10.3%), and postprocedural inflammation in two (2/29; 6.9%). Regarding the timing of cardiac tamponade occurrence, 23 events (23/29; 79.3%) occurred during ablation in the electrophysiology

TABLE 4 Comparison of clinical characteristics between pericarditis group and nonpericarditis group

Demographic variables	All events n = 29	Pericarditis group n = 10	Nonpericarditis group n = 19	*P* value
Age (y ± SD)	64.5 ± 10.4	64.2 ± 12.8	65.3 ± 7.8	0.771
Male, n	22/29 (75.9%)	7/10 (70.0%)	15/19 (78.9%)	0.593
BMI (kg/m^2)	24.2 ± 3.2	25.2 ± 2.5	23.6 ± 3.4	0.203
PAF, n	17/29 (58.6%)	5/10 (50.0%)	12/19 (63.2%)	0.494
LAD (mm)	41.6 ± 5.0	42.2 ± 4.4	41.5 ± 5.4	0.738
LV-EF (%)	68.1 ± 5.6	68.5 ± 3.9	67.9 ± 6.5	0.789
Anticoagulant drugs				
Warfarin use, n	21/29 (72.4%)	7/10 (70.0%)	14/19 (73.7%)	0.833
DOAC use, n	7/29 (24.1%)	2/10 (20.0%)	5/19 (26.3%)	0.766
Onset situations				
EP lab, n	23/29 (79.3%)	7/10 (70.0%)	16/19 (84.2%)	0.369
Ward, n	4/29 (13.8%)	2/10 (20.0%)	2/19 (10.5%)	0.482
Blood type[a]				
Venous blood, n	12/19 (63.2%)	4/6 (66.7%)	8/13 (61.5%)	0.829
Atrial blood, n	7/19 (36.8%)	2/6 (33.3%)	5/13 (38.5%)	0.829
Pericardiocentesis, n	22/29 (75.9%)	7/10 (70.0%)	15/19 (78.9%)	0.593
Hospital stay (days)	11.6 ± 7.1	14.3 ± 4.6	10.2 ± 7.8	0.0048**
Drainage blood (mL)	408 ± 345 (n = 21)	680 ± 485 (n = 7)	272 ± 124 (n = 14)	0.071
Complete procedure, n	19/29 (65.5%)	7/10 (70.0%)	12/19 (63.2%)	0.713
Preventive administration, n	15/29 (51.7%)	2/10 (20.0%)	13/19 (68.4%)	0.013*
Acute recurrence, n	17/29 (58.6%)	6/10 (60.0%)	11/19 (57.9%)	0.913
Midterm recurrence, n	2/29 (6.9%)	0/10 (0.0%)	2/19 (10.5%)	0.288
Pre CRP (mg/dL)	0.41 ± 1.7	0.11 ± 0.1	0.56 ± 2.5	0.498
Max CRP (mg/dL)	6.68 ± 6.5	12.32 ± 7.8	3.71 ± 3.0	0.0002**

Acute recurrence, AF/AT recurrence in acute term; AF, atrial fibrillation; AT, atrial tachycardia; BMI, body mass index; Complete procedure, procedure could be completely ended; DOAC, direct oral anticoagulants; EP, electrophysiological; Hospital stay, the length of hospitalization; LAD, left atrial diameter; LV-EF, left ventricular-ejection fraction; Max CRP, the maximum value of serum C-reactive protein; Midterm AF/AT control; AF/AT control in midterm; PAF, paroxysmal atrial fibrillation; Pre CRP, the preoperative serum C-reactive protein; Preventive administration, preventive administration for pericarditis; SD, standard deviation.

[a]The number of this event was 19 of 29, as the drainage was not performed in seven, and the drainage blood type could not be evaluated in the remaining three events.

*P < 0.05; **P < 0.005.

suite, four (4/29; 13.8%) during the ward stay after the procedure, and two events (2/29; 6.9%) at 10 and 33 days postprocedure. In 19 events (19/29, 65.5%) the ablation procedure was completed, and in 10 (10/29, 34.5%) it could not be completed on the first attempt. There were no instances of cardiac tamponade associated with steam pops.

3.3 | Management of cardiac tamponade

Percutaneous pericardial puncture was performed in 21 events and seven events underwent conservative treatment without puncture. In one event, the puncture could not be performed because of anatomical difficulties (Event 12; Table 2). The average volume of initially drained blood was 408 ± 345 mL (21 events; range, 100-1300 mL; Table 1) and the drain pigtail catheter was placed for an average of 2.5 ± 1.1 days (20 events; range, 0-5 days; Table 2). In seven events (36.8%; 7/19), blood gas analysis showed atrial blood and 12 events (63.2%; 12/19) showed venous blood. The hospital stay was 11.6 ± 7.1 days (range, 4-40 days). No patients died or required surgical repairs and all patients were discharged to their homes.

3.4 | Acute and midterm recurrence

The results of the acute and midterm recurrence of catheter ablation in patients with cardiac tamponade are shown in Figure 1. Among the 19 events of cardiac tamponade, in which catheter ablation was completed, seven events developed acute recurrence of AF or AT (7/19, 36.8%; Table 2). Repeat sessions were performed in the 10 events in which the procedure was not completed and in two in which there was

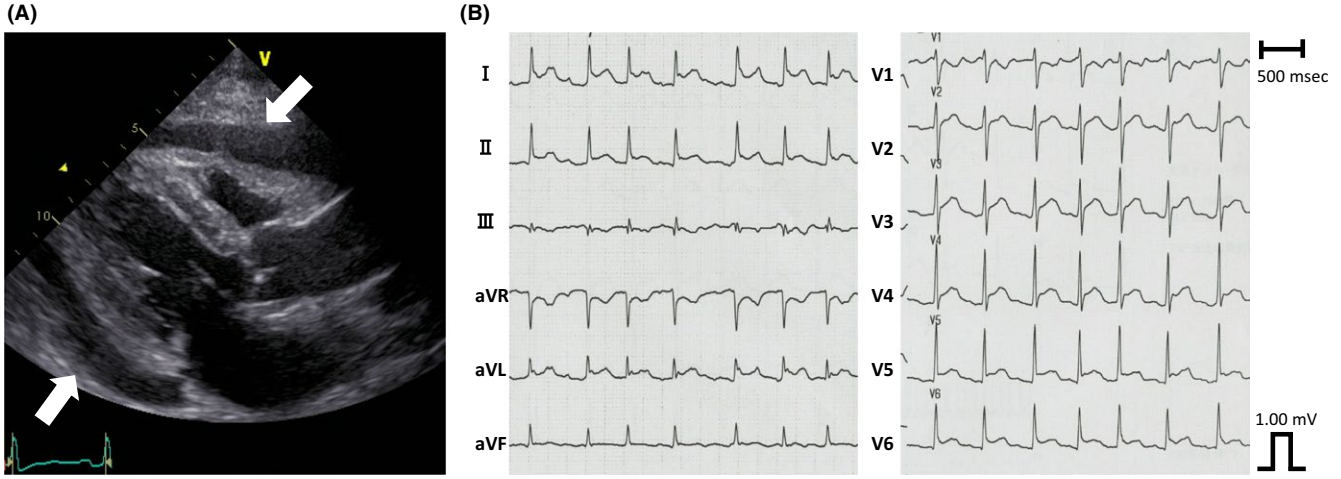


FIGURE 2 A, A case of delayed tamponade (event 20). This figure shows the transthoracic echocardiography (parasternal, long-axis view) 10 days after catheter ablation. Moderate pericardial effusion (white arrow) was observed as a 12 mm thickness around the heart. B, An electrocardiogram (ECG) of pericarditis (event 16). In this patient, atrial fibrillation (AF) recurred with development of pericarditis

AF/AT recurrence over blanking periods of 3 months. Optimal medical therapy was administered in 11 events (37.9%, 11/29; 3 PAF, 4 PerAF, 4 LSPerAF; Table 2) at the discretion of the attending physician in consultation with the patient. By midterm follow-up (3.1 ± 2.6 years), 27 of 29 events were free from AF or AT (nine with medication). Other major complications such as death, congestive heart failure, or stroke were not observed during the follow-up period.

3.5 | Anticoagulant therapy

Anticoagulant therapy was administered in 28 events (96.6%) before catheter ablation (Table 1). Among them, 21 events received warfarin, and seven events received factor Xa inhibitors (apixaban, edoxaban, rivaroxaban) or direct oral thrombin inhibitors (dabigatran etexilate). There was no significant difference in the clinical characteristics and outcomes between the warfarin and DOAC groups. No significant differences in drained blood volume (warfarin group, 340 ± 240 mL vs DOAC group, 417 ± 393 mL; $P = 0.598$) and hospital stay (warfarin group, 11.7 ± 7.53 days, vs DOAC group, 9.9 ± 4.95 days; $P = 0.560$) were observed. Only the rate of venous blood tamponade was significantly higher in the DOAC group [5/5 (100%) vs 7/14 (50.0%); $P = 0.047$; Table 3]. The acute and midterm recurrence rates of AF were not significantly different (Table 3).

3.6 | Pericarditis associated with cardiac tamponade

Among all 29 events, 10 (10/29; 34.5%) developed pericarditis. Most cases of pericarditis developed immediately after cardiac tamponade; however, one developed after discharge from the hospital (Table 2; Event 20). Patients with pericarditis exhibited more severe disease statuses than those without (Table 4). The maximum C-reactive protein values were higher in the cardiac tamponade with pericarditis group than in the cardiac tamponade without pericarditis group (12.32 ± 7.8 vs 3.71 ± 3.0 mg/dL; $P = 0.0002$). The mean hospitalization was also longer in the pericarditis group (14.3 ± 4.6 vs 10.2 ± 7.8 days; $P = 0.0048$). In contrast, there was no statistically significant difference in midterm outcome between the two groups (with pericarditis, 0/10 events, 0.0%; without pericarditis group, 2/19 events, 10.5%; $P = 0.288$). Anti-inflammatory drugs, such as nonsteroidal anti-inflammatories (NSAIDs), or steroids were administered at the attending physician's discretion in 15 events to prevent pericarditis (Table 2). The amount of blood drained in the pericarditis group was higher than that in the nonpericarditis group (680 ± 485 mL vs 272 ± 124 mL; $P = 0.071$). The incidence rate of pericarditis was lower in the group that received prophylactic treatment than in the group that did not (2/15 events, 13.3% vs 8/14 events, 57.1%; $P = 0.013$; odds ratio, 0.115; 95% confidence intervals, 0.019-0.717).

3.7 | Delayed tamponade

In this study, only two events developed delayed tamponade (2/2467, 0.081%). In one event, the patient noticed chest discomfort 10 days after catheter ablation. He visited the emergency room after discharge and pericardial effusion was confirmed via echocardiography (Figure 2A). After pericardiocentesis, there was no reaccumulation of effusion. In another event, cardiac tamponade occurred immediately after PV isolation by cryoballoon and pericardiocentesis was performed at once. Pericarditis occurred 2 days after catheter ablation. NSAIDs and colchicine were prescribed, and after resolution of the pericarditis, the patient was discharged. However, 33 days after catheter ablation, he experienced new-onset dyspnea and presented to the emergency department. We observed increased pericardial fluid and inflow blockage on the echocardiogram, diagnosed him with recurrent cardiac tamponade and performed a repeat

TABLE 5 Comparison with previous literature on cardiac tamponade

	Our study 2018	Latchamsetty et al[13] 2011	Bunch et al[11] 2005
	n = 29	n = 40	n = 15
Incidence of cardiac tamponade	29/2467 (1.18%)	Not mentioned	15/617 (2.4%)
Age (years)	64.5 ± 10.4	61.1 ± 7.8	54 ± 13
Male	22/29 (75.9%)	20/40 (50.0%)	10/15 (66.2%)
PAF	17/29 (58.6%)	28/40 (70.0%)	11/15 (73.3%)
Tamponade by atrial blood	7/19[a] (36.8%)	Not mentioned	9/15 (60.0%)
Pericarditis	10/29 (34.5%)	Not mentioned	8/15 (53.3%)
Hospital stay (days)	11.6 ± 7.1	Not mentioned	6.8 ± 4.8
Surgical operation	0/29 (0.0%)	0/40 (0.0%)	0/15 (0.0%)
Death	0/29 (0.0%)	0/40 (0.0%)	0/15 (0.0%)
Anticoagulant drug			
Warfarin use	21/29 (72.4%)	40/40 (100.0%)	Not mentioned
DOAC use	7/29 (24.1%)	0/40 (0.0%)	Not mentioned
Ablation procedure			
RFCA	20/22[b] (91.0%)	40/40 (100.0%)	15/15 (100.0%)
Balloon ablation	2/22 (9.1%)	0/40 (0.0%)	0/15 (0.0%)
Acute recurrence in hospital	17/29 (58.6%)	20/40 (50.0%)	10/15 (66.7%)
Sinus rhythm maintenance in midterm F/U	27/29 (93.1%) (9 events with AAD; 3.1 ± 2.6 years F/U)	Not mentioned	7/9 (77.8%) (1 patient with AAD; 1.5 ± 1.1 years F/U)

AAD, antiarrhythmic drugs; DOAC, direct oral anticoagulants; F/U, follow-up; Not mentioned, the variable was not mentioned in the study; PAF, paroxysmal atrial fibrillation; RFCA, radiofrequency catheter ablation; Sinus rhythm maintenance in midterm F/U, Sinus rhythm maintenance rate of patients with complete procedure in midterm follow-up.

[a]The number of this event was 19 of 29, as the drainage was not performed in seven, and the drainage blood type could not be evaluated in the remaining three events.

[b]The number of ablation procedure was 22, as cardiac tamponade occurred before ablation procedure in seven events.

pericardiocentesis. The ST elevation on ECG and increased serum C-reactive protein levels supported the diagnosis of recurrent pericarditis.

4 | DISCUSSION

4.1 | Main findings

To the best of our knowledge, this study describes the longest follow-up period for patients with cardiac tamponade associated with ablation for AF. In addition, only a few reports have described pericarditis in patients with cardiac tamponade and the relationship between DOAC and cardiac tamponade. Among the patients with cardiac tamponade in our study, seven events (24.1%) were prescribed DOAC. The acute and midterm recurrence rate were not significantly different in the DOAC and warfarin groups. Pericarditis occurred in 10 events (34.5%) and 17 (58.6%) had an AF/AT recurrence during their respective hospital stays (An example of AF recurrence with pericarditis is shown in Figure 2B). None of the patients required surgical treatment. During midterm follow-up (3.1 ± 2.6 years), 27 events were free from AF or AT (27/29; 93.1%, nine events with antiarrhythmic medication).

4.2 | Acute and midterm outcome in cardiac tamponade cases

While previous studies have reported frequency of cardiac tamponade, midterm outcomes are lacking. In this study, the overall acute AF/AT recurrence rate was 58.6% (17/29). In 19 events that underwent complete ablation, the acute AF/AT rate was 36.8% (7/19). Conversely, patients in the incomplete ablation group had a higher AF/AT recurrence rate (100.0%). The results suggest that complete ablation can help reduce the acute recurrence rate. In addition, 2 of the 19 events in the complete ablation group and all

10 in the incomplete group required redo sessions after blanking periods of 3 months and most events maintained sinus rhythm at midterm follow-up (27/29, 93.1%, with antiarrhythmic medication). This shows that even if tamponade occurs, proper diagnosis and treatment could prevent serious complications such as death or other unrecoverable states. If the patient survives the acute perioperative period and the repeat procedures are performed properly, sinus rhythm maintenance could be expected, similarly to normal patients. This result was similar with a previous study by Bunch et al[11] (Table 5), which reported a high rate of sinus rhythm maintenance in midterm (7/9, 77.8%, 1 patient with antiarrhythmic drug, 1.5 ± 1.1 years follow-up). However, it bears mentioning that these favorable results were achieved at a high volume center with expert electrophysiologists.

4.3 | Causes of cardiac tamponade

A previous paper had reported that steam pops can cause cardiac tamponade during ablation of ventricular arrhythmias, and that surgical repair was often needed.[12] Although cardiac tamponade attributable to steam pop was also reported during AF ablation,[4] no such incidents occurred in this study. This may be due to the magnitude of energy applied, which is limited to 35 W at our institution. Atrial bleeding could be caused by injury to the left atrial appendage, left atrial roof, or PVs. In contrast, venous bleeding occurs secondary to damage the right atrium, right ventricle, or coronary sinus. This indicates the importance of catheter manipulation in the right side of the heart as well as the left side during AF ablation in patients on anticoagulation.

4.4 | Anticoagulant therapy

The standard procedures for catheter ablation are changing and the number of patients requiring AF ablation continues to increase worldwide. It is common to perform AF ablation while continuing anticoagulant therapy. As long as the PT-INR is maintained within the appropriate range, bleeding complications are rare, even with warfarin treatment.[12] All our patients underwent catheter ablation while on anticoagulant therapy. This study is the first report to describe pericarditis and cardiac tamponade related to AF ablation in patients receiving anticoagulant therapy, including DOAC. Similar to past reports of warfarin use in[11,13] cardiac tamponade, DOAC may be fully manageable if proper supports are given.

4.5 | Pericarditis with cardiac tamponade

A case of pericarditis complicated with cardiac tamponade was previously reported by Bunch et al[11] in a study where 8 of 15 patients (53.3%) developed pericarditis (Table 5). In our study, 10 events (10/29, 34.5%) developed pericarditis after cardiac tamponade (Table 4). The events with pericarditis required longer hospital stays (14.3 ± 4.6 days). Subsequent pericarditis was less frequent in the group that received prophylactic treatment than in the group that did not (2/15, 13.3% vs 8/14, 57.1%; $P = 0.013$). The cause of pericarditis after cardiac tamponade is still unclear. The maximum value of serum C-reactive protein was higher in the pericarditis group (12.32 ± 7.8 vs in nonpericarditis Group, 3.71 ± 3.0, $P = 0.0002$; Table 4), presumably caused by the pericarditis itself. Although there was no significant difference in the drainage volume between the two groups (680 ± 485 mL in pericarditis group vs 272 ± 124 mL in nonpericarditis group; $P = 0.071$), pericarditis tended to occurs when the volume exceeded 600 mL. In such circumstances, the administration of anti-inflammatory drugs should be considered to prevent pericarditis.

4.6 | Delayed tamponade

Similarly to "Dressler syndrome" and "postcardiac injury syndrome," late-onset pericarditis after catheter ablation has been reported.[14-16] The onset of these conditions can vary from within a few days to a few weeks after procedure. Although the pathogenesis is unclear, inflammation of the ablation region or rupture of a hematoma on the pericardial side are possible causes of this rarecomplication.[7] In this study, only two events developed delayed tamponade (2/2467, 0.081%). Both patients had been checked for excess pericardial fluid before discharge; therefore, we suspect that the pericardial effusion increased during the postdischarge subacute phase. Even at several weeks after the procedure, it is necessary to pay attention to changes in the patient's physical condition as there is a possibility, albeit low, that delayed tamponade will occur.

4.7 | Limitations

The study has some limitations. First, we retrospectively examined a small (29) number of events from a single center. Second, the AF/AT recurrences were diagnosed based on the patient's symptoms and regular follow-up 12-lead ECGs, 24-h Holter monitoring, or event recordings. Recurrence after ablation can be asymptomatic and we, therefore, may have missed some cases. Third, we used the contact force system in only 10 events because of insurance-related concerns. The use of a contact force system may affect the occurrence of cardiac tamponade as its incidence may be decreased if excessive contact is avoided. Finally, the rate of occurrence of cardiac tamponade depends on the experience of both the operator and the institute. Thus, in a different setting, the results may differ.

5 | CONCLUSION

Cardiac tamponade is a serious complication of the catheter ablation procedure for AF, and acute AT/AF recurrence and pericarditis are quite common. If the ablation procedure can be completed before the occurrence of cardiac tamponade, or a repeat ablation procedure scheduled later, the midterm outcomes of AF ablation may be unaffected.

CONFLICT OF INTEREST

Dr. Nogami, Dr. Aonuma, and Dr. Sekiguchi belong to the endowed department of Medtronic, Toray Industries, and Abbott, respectively. The other authors report no conflicts.

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How to cite this article: Yui Y, Sekiguchi Y, Nogami A, et al. Midterm outcomes of catheter ablation for atrial fibrillation in patients with cardiac tamponade. *J Arrhythmia*. 2019;35:109–120. https://doi.org/10.1002/joa3.12127