

Long-term clinical impact of early recurrence of atrial tachyarrhythmia after cryoballoon ablation in patients with atrial fibrillation

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Abstract

Introduction: The impact of early recurrence of atrial tachyarrhythmia (ERAT) within the 90-day blanking period on long-term outcomes in atrial fibrillation (AF) patients undergoing cryoballoon ablation (CBA) is controversial. This study aimed to assess the relationship between ERAT and late recurrence of atrial tachyarrhythmia (LRAT) post-CBA.

Methods: Utilizing data from a multicenter registry in Korea (May 2018 to June 2022), we analyzed the presence and timing of ERAT (<30, 30–60, and 60–90 days)

Abbreviations: AF, atrial fibrillation; CBA, cryoballoon ablation; CI, confidence interval; ERAT, early recurrence of atrial tachyarrhythmia; HR, hazard ratio; LA, left atrium; LRAT, late recurrence of atrial tachyarrhythmia; RFA, radiofrequency ablation.

Myung-Jin Cha and Chang Hee Kwon contributed equally to this study.

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Disclosures: None.

Funding information

Korean Heart Rhythm Society,
Grant/Award Number: 2021-3

and its association with LRAT risk after CBA. LRAT was defined as any recurrence of AF, atrial flutter, or atrial tachycardia lasting more than 30 s beyond the 90 days.

Results: Out of 2636 patients, 745 (28.2%) experienced ERAT post-CBA. Over an average follow-up period of 21.2 ± 10.3 months, LRAT was observed in 874 (33.1%) patients. Patients with ERAT had significantly lower 1-year LRAT freedom compared to those without ERAT (42.6% vs. 85.5%, $p < .001$). Multivariate analysis identified ERAT as a potential predictor of LRAT, with a hazard ratio (HR) of 3.98 (95% confidence interval [CI], 3.47–4.57). Significant associations were noted across all examined time frames (HR, 3.84; 95% CI, 3.32–4.45 in <30 days, HR, 5.53; 95% CI, 4.13–7.42 in 30–60 days, and HR, 4.29; 95% CI, 3.12–5.89 in 60–90 days). This finding was consistently observed across all types of AF.

Conclusion: ERAT during the 90-day blanking period strongly predicts LRAT in AF patients undergoing CBA, indicating a need to reconsider the clinical significance of this period.

KEYWORDS

atrial fibrillation, blanking period, cryoballoon ablation, recurrence

1 | INTRODUCTION

The use of a “blanking period,” typically defined as the first 90 days following catheter ablation for atrial fibrillation (AF), is common practice. Early recurrences of atrial tachyarrhythmia (ERAT) during this period are not deemed failures of the ablation due to their temporary nature. These are regarded as transient arrhythmias associated with post-procedural inflammation and recovery.^{1,2} However, recent studies have reported that the occurrence and timing of ERAT within the blanking period are predictive of long-term AF recurrence, with ERAT occurring later in the blanking period being particularly indicative of a higher risk of AF recurrence.^{3–6}

A survey by the European Heart Rhythm Association highlighted an inclination among physicians towards shortening the 90-day blanking period for patients with paroxysmal AF, despite overall adherence to the existing standard. Notably, in patients with persistent AF, half of the surveyed physicians considered ERAT as a predictor of late AF recurrence, likely influenced by studies linking ERAT, especially later in the blanking period, to increased rates of late recurrences.³ This consensus points to a potential need for reevaluating the standardized 90-day blanking period.

Given the distinct lesion characteristics produced by cryoballoon ablation (CBA)—dense, well-demarcated, and homogeneous due to the freezing process—compared to those produced by radiofrequency ablation (RFA),⁷ the suitability of the blanking period for CBA is questionable. Therefore, we aimed to evaluate the temporal relationship between ERAT and late recurrence of atrial tachyarrhythmia (LRAT) following CBA in patients with AF.

2 | METHODS

2.1 | Study population

This retrospective analysis utilized data from the Korean Nationwide Cryoballoon Ablation Registry, encompassing 12 tertiary institutes from May 2018 to June 2022. A total of 2689 patients who underwent de novo CBA for the treatment of drug-refractory AF were consecutively enrolled. Patients lost to follow-up within the 90-day blanking period post-CBA ($n = 18$) and those with incomplete data ($n = 35$) were excluded, resulting in 2636 patients being included in the analysis (Figure 1). Study patients were divided into two groups: the ERAT group, consisting of individuals who experienced any atrial tachyarrhythmia within the 90-day blanking period post-CBA, and the No ERAT group, comprising those without such occurrences. Additionally, the ERAT group was subdivided based on the timing of ERAT occurrence (<30, 30–60, and 60–90 days). Institutional Review Board approval was obtained from Asan Medical Center and each participating institution.

2.2 | CBA procedure

The procedure involved a transseptal puncture for left atrial access, utilizing a 15-F deflectable sheath (FlexCath, MedtronicA). Pulmonary vein potentials were recorded using a circular mapping catheter (Achieve, Medtronic). Cryoenergy was delivered using a 28-mm second-generation Arctic Front Advance balloon (Medtronic), adhering generally to practice guidelines for CBA in AF patients. Operators had discretion over specific procedural aspects such as cryoenergy delivery time, fluoroscopic or intracardiac

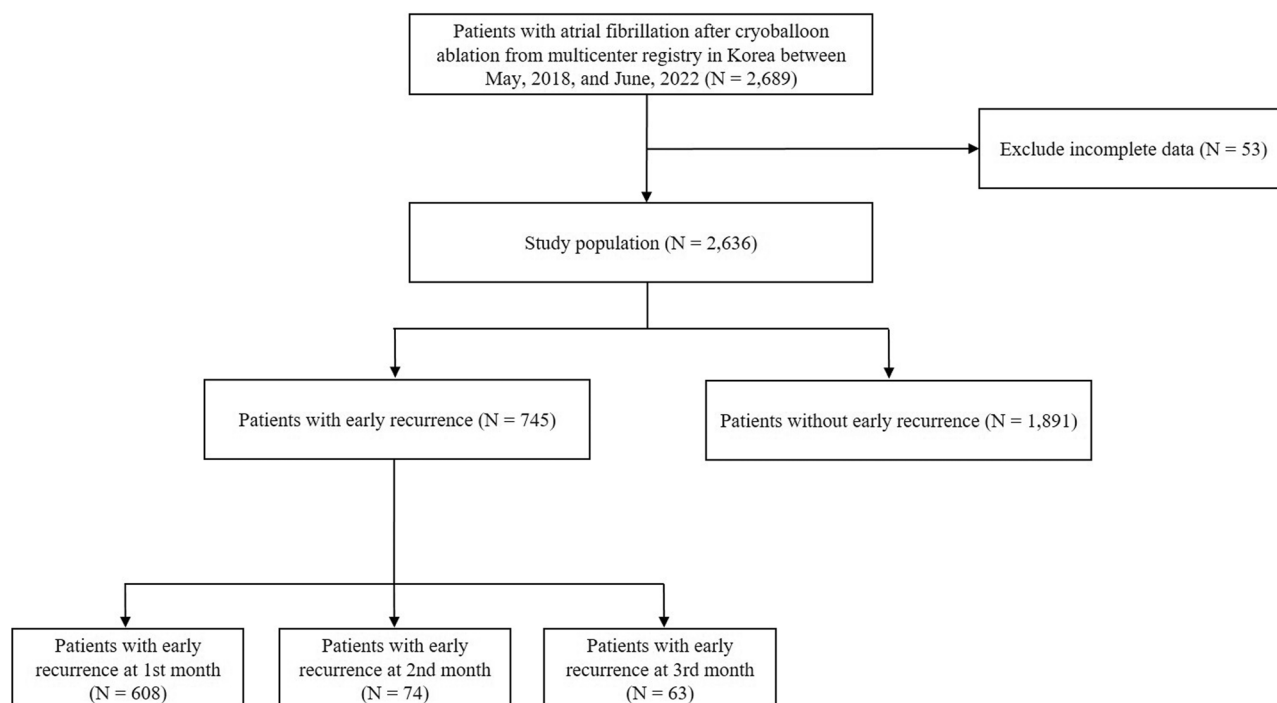


FIGURE 1 Study flow.

echocardiographic guidance, use of general anesthesia, and postablation testing.⁸

Diaphragmatic stimulation with high output pacing of the ipsilateral phrenic nerve was performed during right-sided ablations to prevent phrenic nerve paralysis, ceasing upon detection of reduced diaphragmatic response. Additional radiofrequency catheter ablation of the cavotricuspid isthmus was performed based on the operator's discretion. Peri-procedural anticoagulation, management of antiarrhythmic drugs, and discharge followed the standard-of-care practice of each hospital.

2.3 | Patient follow-up and study outcomes

Follow-up was systematically conducted at 1, 3, 6, 9, and 12 months post-CBA, thereafter every 3–6 months or as clinical symptoms emerged. Follow-up monitoring adhered to current guidelines and standard-of-care practices of each hospital. Monitoring methods included a 12-lead electrocardiogram, Holter monitoring, or a single-lead electrocardiogram patch recording. ERAT was defined as any recurrence of AF, atrial flutter, or atrial tachycardia lasting more than 30 s within the 90-day blanking period. The primary study outcome was late recurrent atrial tachyarrhythmia (LRAT), which is defined identically to early recurrent atrial tachyarrhythmia (ERAT) as any episode of AF, atrial flutter, or atrial tachycardia lasting more than 30 s, but specifically occurring after the 90-day blanking period. The secondary study outcome assessed the incidence of LRAT based on ERAT timing in patients with paroxysmal or persistent AF.

2.4 | Statistical analysis

Continuous variables are presented as mean $\pm$ standard deviation, analyzed using Student's *t* tests or Wilcoxon rank-sum tests (for non-normally distributed data) as appropriate. Categorical variables are presented as numbers (percentages) and analyzed using χ^2 tests or Fisher's exact tests. LRAT time was depicted using the Kaplan–Meier method and compared via the log-rank test. Univariate and multivariate logistic regression analyses identified factors associated with ERAT and LRAT. The Cox proportional hazard model assessed the impact of ERAT's presence and timing on LRAT. All *p* values were two-sided, with values $< .05$ deemed significant. Statistical analyses were performed using the R statistical package, version 4.2.3 (<http://www.r-project.org>).

3 | RESULTS

3.1 | Baseline characteristics of study patients

The mean age of the study patients was 61.7 years, with 76.7% being male. Among them, 745 (28.3%) experienced ERAT after CBA: 608 (81.6%) within the first 30 days, 74 (9.9%) between 30 and 60 days, and 63 (8.5%) between 60 and 90 days. Detailed baseline characteristics comparing patients with and without ERAT are outlined in Table 1. Those experiencing ERAT had a longer AF duration, a higher proportion of persistent AF, and a larger left atrial size compared to those without ERAT. The prevalence of comorbidities such as hypertension, diabetes, and coronary artery disease, alongside the mean CHA₂DS₂-VASc score, showed no significant differences between the two groups. Notably, the

TABLE 1 Baseline characteristics of study patients.

Characteristic	Total (N = 2636)	No ERAT (N = 1891)	ERAT (N = 745)	p Value
Age (years)	61.7 ± 10.0	61.5 ± 10.3	62.2 ± 9.3	.09
Male sex, n (%)	2,022 (76.7%)	1,463 (77.4%)	559 (75.0%)	.221
Body mass index (kg/m ²)	25.7 ± 3.4	25.6 ± 3.4	25.8 ± 3.4	.215
AF duration (years)	3.1 ± 3.3	2.9 ± 3.1	3.7 ± 3.8	<.001
Type of AF, n (%)				
Paroxysmal	1,171 (44.4%)	967 (51.1%)	204 (27.4%)	<.001
Persistent	1,465 (55.6%)	924 (48.9%)	541 (72.6%)	
Congestive heart failure, n (%)	618 (23.4%)	434 (23.0%)	184 (24.7%)	.367
Hypertension, n (%)	1,517 (57.5%)	1,094 (57.9%)	423 (56.8%)	.646
Diabetes mellitus, n (%)	568 (21.5%)	403 (21.3%)	165 (22.1%)	.676
Previous Stroke/TIA, n (%)	306 (11.6%)	222 (11.7%)	84 (11.3%)	.775
Coronary artery disease, n (%)	212 (8.0%)	145 (7.7%)	67 (9.0%)	.295
CHA ₂ DS ₂ -VASc score	2.1 ± 1.5	2.1 ± 1.6	2.1 ± 1.5	.614
Mitral valve disease, n (%)	26 (1.0%)	18 (1.0%)	8 (1.1%)	.947
Hypertrophic cardiomyopathy, n (%)	59 (2.2%)	42 (2.2%)	17 (2.3%)	1.000
Left atrial size (mm)	43.8 ± 6.3	42.9 ± 6.1	46.0 ± 6.4	<.001
Left ventricular ejection fraction (%)	58.6 ± 8.6	58.8 ± 8.7	58.2 ± 8.1	.132
Cavotricuspid isthmus ablation	577 (21.9%)	465 (24.6%)	112 (15.0%)	<.001

Abbreviations: AF, atrial fibrillation; ERAT, early recurrence of atrial tachyarrhythmia; TIA, transient ischemic attack.

rate of concomitant cavotricuspid isthmus ablation was higher in patients without ERAT (24.5% vs. 15.0%, $p < .001$).

3.2 | LRAT according to the presence and timing of ERAT

The 1-year freedom from LRAT was significantly lower in patients with ERAT (42.6%) compared to those without (85.5%) (Figure 2A, $p < .001$). Specifically, within the ERAT cohort, the 1-year freedom from LRAT was 44.1% for ERAT within 30 days, 32.4% for ERAT between 30 and 60 days, and 39.0% for ERAT between 60 and 90 days ($p = .051$) (Figure 2B). An analysis was conducted on the primary outcome, excluding patients

who underwent CTI ablation, and the same trend regarding the clinical significance of LRAT and ERAT as in the previous analysis was observed (Supporting Information S1: Figure 1).

3.3 | Subgroup analysis based on the type of AF

In patients with paroxysmal AF, the 1-year freedom from LRAT was significantly lower in those with ERAT (52.6%) compared to those without (87.2%; $p < .001$, Figure 2C). Similarly, among individuals with persistent AF, those with ERAT experienced significantly lower 1-year freedom from LRAT (37.4%) than those without ERAT (83.8%; $p < .001$, Figure 2D). Additional analyses were conducted to explore potential trends in patients with long-standing persistent AF and across subgroups of early recurrence of atrial tachycardia (ERAT) (<1, 1–2, and 2–3 months). Results indicated no significant differences in ERAT incidence among different durations of persistent AF or between long-standing AF and non-long-standing AF groups. These findings are presented as supplementary data (Supporting Information S1: Figure 2). Moreover, the timing of ERAT did not significantly affect the 1-year freedom from LRAT in both paroxysmal and persistent AF categories. According to the Cox proportional hazard model, both the presence and timing of ERAT notably increased the risk of LRAT at the 1-year follow-up for both groups (Table 2).

3.4 | Predictors of LRAT

The analysis of variables predicting LRAT is detailed in Table 3 and illustrated in Figure 3. Unadjusted univariate analysis revealed a significantly higher risk of LRAT associated with persistent AF, mitral valve disease, or hypertrophic cardiomyopathy (Figure 3). According to the Cox proportional hazard model, the occurrence of ERAT emerged as the most potent predictor of LRAT, with a hazard ratio [HR] of 3.98 (95% confidence interval [CI], 3.47–4.57; $p < .001$). Multivariable analysis further highlighted ERAT at all evaluated time points as a significant predictor of LRAT, presenting HRs of 3.84 for ERAT within 30 days (95% CI, 3.32–4.45; $p < .001$), 5.53 for ERAT between 30 and 60 days (95% CI, 4.13–7.42; $p < .001$), and 4.29 for ERAT between 60 and 90 days (95% CI, 3.12–5.89; $p < .001$). Additionally, persistent AF (HR, 1.39; 95% CI, 1.19–1.62; $p < .001$), duration of AF (HR, 1.02; 95% CI, 1.00–1.04; $p = .02$), history of ischemic stroke (HR, 1.29; 95% CI, 1.01–1.63; $p < .001$), and left atrial size (HR, 1.04; 95% CI, 1.02–1.05; $p < .001$) were identified as significantly associated with the occurrence of LRAT. Conversely, male sex (HR, 0.82; 95% CI, 0.69–0.97; $p = .022$) and concomitant cavotricuspid isthmus ablation (HR, 0.82; 95% CI, 0.68–0.98; $p = .034$) significantly lowered the risk of LRAT (Table 3).

3.5 | LRAT in patients with ERAT

Among patients experiencing ERAT, baseline characteristics linked to the presence of LRAT are outlined in Table 4. Significantly, the

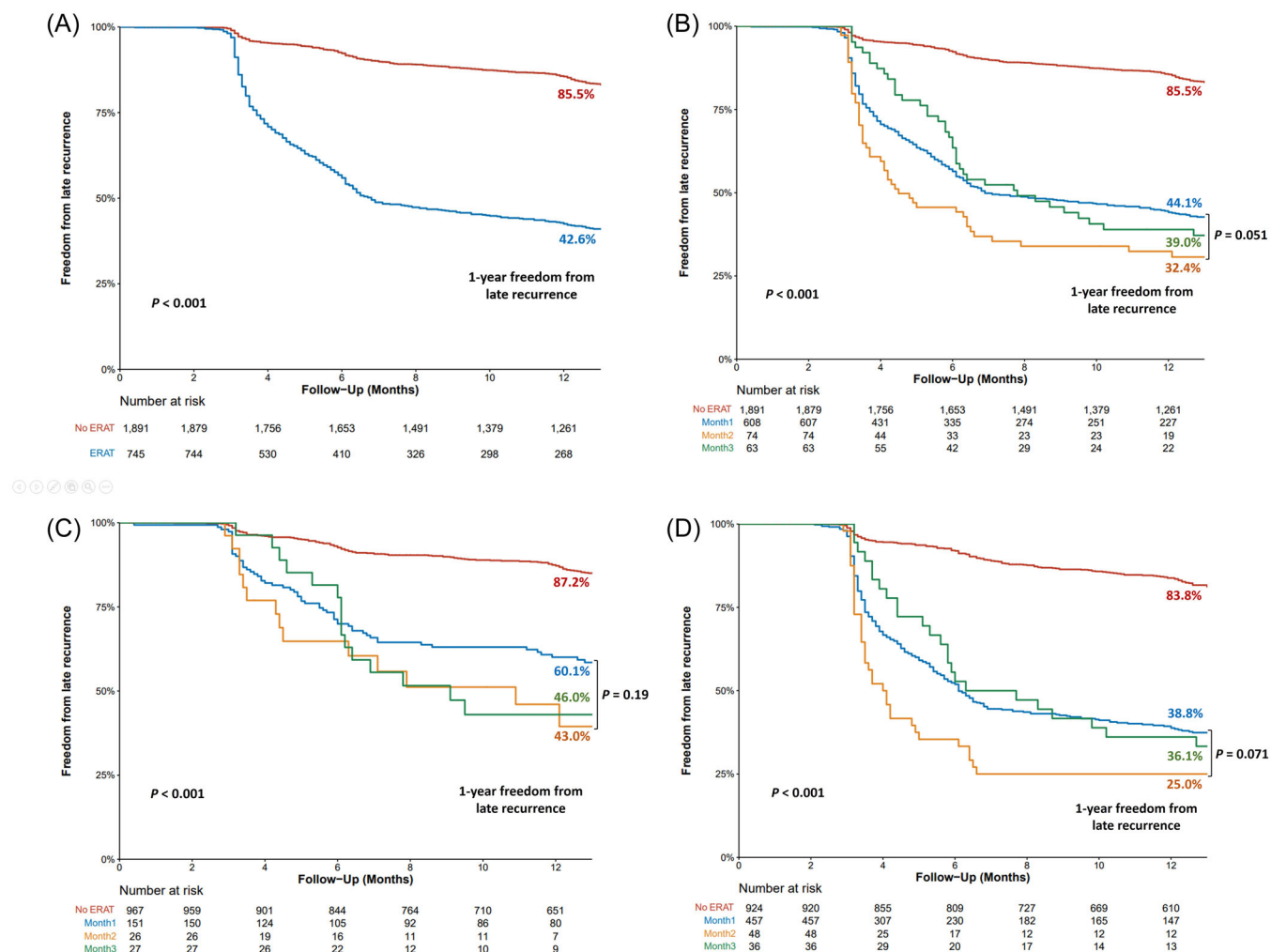


FIGURE 2 One-year freedom from LRAT after cryoballoon ablation, stratified according to ERAT (A), the timing of ERAT (B), in patients with paroxysmal AF (C), and patients with persistent AF (D). AF, atrial fibrillation; ERAT, early recurrence of atrial tachyarrhythmia; LRAT, late recurrence of atrial tachyarrhythmia.

TABLE 2 Impact of ERAT stratified by type of atrial fibrillation.

Group	Univariate analysis			Multivariate analysis		
	HR	95% CI	p Value	HR	95% CI	p Value
Paroxysmal AF						
ERAT	3.95	3.10–5.04	<.001	3.08	1.98–4.78	<.001
ERAT ≤ 30 days	3.60	2.74–4.72	<.001	3.41	2.58–4.50	<.001
30 < ERAT ≤ 60 days	6.17	3.68–10.3	<.001	5.66	3.37–9.52	<.001
60 < ERAT ≤ 90 days	4.61	2.76–7.71	<.001	4.12	2.46–6.91	<.001
Persistent AF						
ERAT	4.43	3.74–5.24	<.001	3.87	2.94–5.09	<.001
ERAT ≤ 30 days	4.32	3.63–5.15	<.001	4.08	3.42–4.87	<.001
30 < ERAT ≤ 60 days	6.37	4.50–9.01	<.001	5.69	3.97–8.14	<.001
60 < ERAT ≤ 90 days	4.59	3.07–6.85	<.001	4.40	2.93–6.58	<.001

Abbreviations: AF, atrial fibrillation; CI, confidence interval; ERAT, early recurrence of atrial tachyarrhythmia; HR, hazard ratio.

TABLE 3 Risk factors for late recurrence of atrial tachyarrhythmia.

Characteristic	Univariate analysis			Multivariate analysis		
	HR	95% CI	p Value	HR	95% CI	p Value
ERAT	4.59	4.01–5.25	<.001	3.98	3.47–4.57	<.001
ERAT ≤ 30 days	4.46	3.87–5.14	<.001	3.84	3.32–4.45	<.001
30 < ERAT ≤ 60 days	6.66	5.00–8.86	<.001	5.53	4.13–7.42	<.001
60 < ERAT ≤ 90 days	4.70	3.43–6.44	<.001	4.29	3.12–5.89	<.001
Age	1.00	0.99–1.00	.5			
Sex, male	0.97	0.83–1.13	.7	0.82	0.69–0.97	.022
Body mass index	1.01	0.99–1.03	.2			
AF duration	1.04	1.03–1.06	<.001	1.02	1.00–1.04	.020
Persistent AF	1.95	1.69–2.24	<.001	1.39	1.19–1.62	<.001
Congestive heart failure	0.96	0.82–1.13	.6			
Hypertension	0.88	0.77–1.00	.054			
Diabetes mellitus	0.96	0.82–1.13	.6			
Previous stroke/TIA	1.01	0.83–1.24	.9	1.29	1.01–1.63	.038
Coronary artery disease	0.89	0.69–1.14	.3			
Mitral valve disease	1.80	1.06–3.05	.030			
Hypertrophic cardiomyopathy	1.58	1.10–2.27	.014			
Left atrial size	1.06	1.05–1.07	<.001	1.04	1.02–1.05	<.001
Left ventricular ejection fraction	0.99	0.99–1.00	.089			
Cavotricuspid isthmus ablation	0.66	0.55–0.78	<.001	0.82	0.68–0.98	.034

Abbreviations: AF, atrial fibrillation; CI, confidence interval; ERAT, early recurrence of atrial tachyarrhythmia; HR, hazard ratio; TIA, transient ischemic attack.

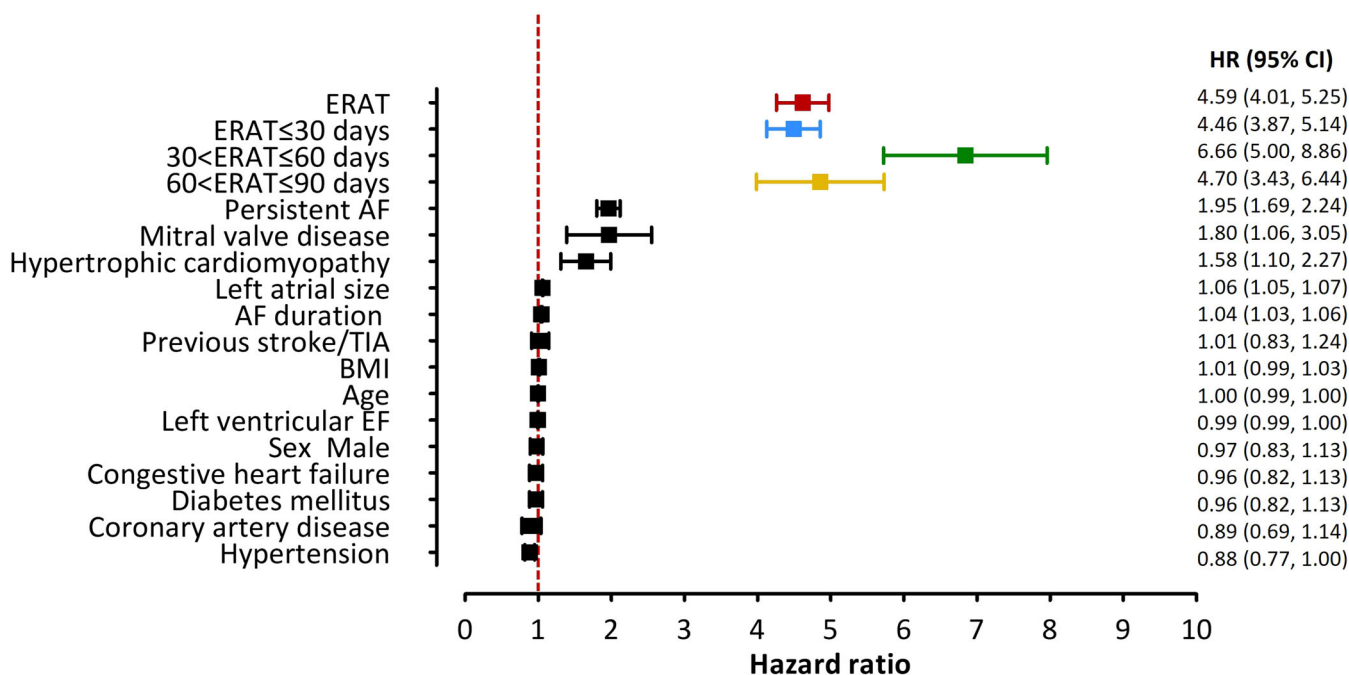
**FIGURE 3** Forest plot of unadjusted hazard ratio for LRAT. LRAT, late recurrence of atrial tachyarrhythmia.

TABLE 4 Baseline characteristics of patients with ERAT: Comparison by LRAT presence.

Characteristic	Total (N = 745)	No LRAT (N = 272)	LRAT (N = 473)	p Value
Age (years)	62.2 ± 9.3	62.5 ± 10.1	62.0 ± 8.8	.494
Male sex, n (%)	559 (75.0%)	203 (74.6%)	356 (75.3%)	.917
Body mass index (kg/m ²)	25.8 ± 3.4	25.8 ± 3.4	25.8 ± 3.3	.783
AF duration (years)	3.7 ± 3.8	3.3 ± 3.3	3.9 ± 4.0	.023
Type of AF, n (%)				
Paroxysmal	204 (27.4%)	95 (34.9%)	109 (23.0%)	<.001
Persistent	541 (72.6%)	177 (65.1%)	364 (77.0%)	
Congestive heart failure, n (%)	184 (24.7%)	75 (27.6%)	109 (23.0%)	.196
Hypertension, n (%)	423 (56.8%)	164 (60.3%)	259 (54.8%)	.164
Diabetes mellitus, n (%)	165 (22.1%)	60 (22.1%)	105 (22.2%)	1
Previous stroke/TIA, n (%)	84 (11.3%)	32 (11.8%)	52 (11.0%)	.841
Coronary artery disease, n (%)	67 (9.0%)	28 (10.3%)	39 (8.2%)	.419
CHA ₂ DS ₂ -VASc score	2.1 ± 1.5	2.3 ± 1.5	2.0 ± 1.4	.034
Mitral valve disease, n (%)	8 (1.1%)	3 (1.1%)	5 (1.1%)	1
Hypertrophic cardiomyopathy, n (%)	17 (2.3%)	5 (1.8%)	12 (2.5%)	.719
Left atrial size (mm)	46.0 ± 6.4	45.0 ± 6.2	46.5 ± 6.4	<.001
Left ventricular ejection fraction (%)	58.2 ± 8.1	58.7 ± 8.5	58.0 ± 7.9	.24
Cavotricuspid isthmus ablation	112 (15.0%)	49 (18.0%)	63 (13.3%)	.105

Abbreviations: AF, atrial fibrillation; ERAT, early recurrence of atrial tachyarrhythmia; LRAT, late recurrence of atrial tachyarrhythmia; TIA, transient ischemic attack.

duration of AF, the proportion of persistent AF, and LA size were markedly higher in patients who developed LRAT. The rates of concurrent cavotricuspid isthmus ablation were found to be similar across patients regardless of LRAT status (Table 4). According to the Cox proportional hazard model, persistent AF (HR, 1.44; 95% CI, 1.15–1.81; $p = .002$) and increased LA size (HR, 1.02; 95% CI, 1.01–1.04; $p = .002$) were significantly associated with a higher risk of LRAT occurrence (Table 5).

4 | DISCUSSION

In this comprehensive, multicenter, population-based retrospective analysis, we sought to clarify the temporal relationship between ERAT and the subsequent risk of LRAT following CBA in patients with AF. The principal findings of our study are as follows: (1) ERAT was identified as the most significant risk factor for LRAT, (2) ERAT occurring at any point within the 90-day blanking period significantly predicted LRAT, (3) the clinical impact of the presence and timing of ERAT was consistently substantial among patients with both paroxysmal and persistent AF undergoing CBA, and (4) persistent AF and increased LA size were identified as significant predictors of LRAT in patients experiencing ERAT.

The occurrence of ERAT has been associated with transient proarrhythmogenic effects resulting from ablation procedures, such

as inflammation, oxidative stress, edema, tissue repair processes, and autonomic imbalance.^{1,9,10} Observational studies have previously noted that roughly 50% of patients experiencing ERAT do not go on to have further symptomatic AF during long-term follow-up.^{1,2} In light of these findings, an expert consensus has advocated for a 90-day blanking period postablation, during which recurrences of arrhythmia are not considered indicative of ablation failure.¹¹ Nonetheless, the benign nature of ERAT and its impact on LRAT has remained a subject of debate.^{3,6,12} Additionally, the optimal duration of the blanking period has yet to be definitively established.^{9,13} While some observational studies suggested that ERAT occurring after the first 30 days postablation is indicative of genuine pulmonary vein reconnection and thus a harbinger of actual late recurrence,^{13,14} our research indicates that patients experiencing ERAT within the initial 30 days are also at a significantly heightened risk of LRAT compared to those without ERAT. According to recent guideline discussions advocating for an 8-week blanking period, we reanalyzed ERAT within an 8-week timeframe.¹⁵ Even in this scenario, patients experiencing ERAT within 8 weeks exhibited significantly higher rates of LRAT (see Supporting Information S1: Figure 3). Given that our cohort revealed no significant differences among the 1, 2, and 3-month ERAT subgroups, it is conceivable that all subgroups pose significant risk factors for LRAT.

TABLE 5 Predictor of late recurrence among patients with ERAT: Analysis using Cox proportional hazards regression models.

Characteristic	Univariate analysis			Multivariable analysis		
	HR	95% CI	p Value	HR	95% CI	p Value
Age	1.00	0.99–1.00	.4			
Sex, male	1.09	0.88–1.34	.4			
Body mass index (kg/m ²)	1.00	0.98–1.03	.9			
AF duration	1.03	1.01–1.06	.006	1.02	1.00–1.05	.053
Persistent AF	1.61	1.30–2.00	<.001	1.44	1.15–1.81	.002
Congestive heart failure	0.87	0.70–1.08	.2	0.77	0.62–0.96	.020
Hypertension	0.91	0.76–1.09	.3			
Diabetes mellitus	1.07	0.86–1.33	.6			
Previous stroke/TIA	0.89	0.67–1.19	.4			
Coronary artery disease	0.93	0.67–1.29	.6			
Mitral valve disease	1.03	0.43–2.50	>.9			
Hypertrophic cardiomyopathy	1.26	0.71–2.24	.4			
Left atrial size	1.03	1.02–1.04	<.001	1.02	1.01–1.04	.002
Left ventricular ejection fraction	0.99	0.98–1.01	.3			
Cavotricuspid isthmus ablation	0.72	0.55–0.94	.016	0.84	0.64–1.10	.2

Abbreviations: AF, atrial fibrillation; CI, confidence interval; ERAT, early recurrence of atrial tachyarrhythmia; HR, hazard ratio; TIA, transient ischemic attack.

The establishment of a blanking period following RFA is fundamentally based on the mechanical effects of thermal injury and the heterogeneity of the resulting lesions. In contrast, CBA produces lesions that are dense, well-demarcated, and homogenous due to the direct freezing process, necessitating a reevaluation and distinct definition of the blanking period post-CBA. Thus, the significance of ERAT is presumed to differ between RFA and CBA, although this study cannot precisely estimate its exact mechanism. Previous observational studies have shown that ERAT significantly predicts LRAT in patients undergoing CBA.^{4,16–21} However, these studies were conducted in relatively small cohorts,^{4,16,19–21} while our present study distinguishes itself as a nationwide, multicenter investigation involving a substantial population. While our findings align with those of prior studies, this large-scale investigation offers significant insights into the long-term implications of ERAT following CBA. Moreover, our results highlight that ERAT, irrespective of its occurrence within the 90-day blanking period, significantly influences the risk of LRAT following CBA. Additionally, our study found that among patients with persistent AF who did not experience ERAT, the 1-year freedom from LRAT was 83.8%, a rate comparable to the 87.2% observed in patients with paroxysmal AF. Conversely, these findings imply that ERAT may not be a benign phenomenon following CBA. With ERAT identified as the most significant predictor of LRAT, even after adjusting for other important variables such as the duration of AF, presence of persistent AF, and left atrial size, it suggested that ERAT could truly represent an early recurrence of AF. Furthermore, the risk factors for LRAT among patients with ERAT align with those identified in the broader patient population.

This similarity suggests that the presence of these risk factors in individuals with ERAT points to a significant probability of genuine AF recurrence. Given the occurrence of ERAT, it becomes imperative to have in-depth discussions about treatment options and prognosis, acknowledging the increased risk of LRAT.

In the present study, a significant portion (81.6%) of ERAT manifested within 30 days following CBA, with nearly half (43.9%) occurring within the first 2 weeks. This observation aligns with previous studies indicating that up to 73% of ERAT instances arise within the initial 30 days, with about 50% within 2 weeks.^{16,20} Contrastingly, studies focusing on RFA suggest that early recurrences tend to manifest later, with Oral et al. reporting that 35.5% of ERAT cases occurred within 2 weeks,² and most studies noting ERAT rates below 40% within 1 month.^{22–27} This pattern suggests that ERAT may occur more promptly following CBA as compared to RFA. Wei et al. have shown that postablation inflammation is more pronounced in RFA than in CBA, evidenced by elevated levels of inflammatory markers such as cardiac troponin I, C-reactive protein, and the neutrophil to lymphocyte count ratio.²⁸ This heightened inflammatory response could play a significant role in ERAT following RFA. In contrast, the CBA group experiences a less pronounced extent of nonspecific injury and subsequent inflammatory response, indicating that the actual blanking period could be significantly shorter or even less consequential. Regarding the optimal blanking period for patients undergoing CBA, Steinberg et al. suggested that ERAT in patients without LRAT typically occurs at a median of 10.0 days (interquartile range 5.0–19.0; area under the curve 0.79; 95% CI, 0.77–0.81; $p < .001$), with ERAT associated with LRAT occurring later.²⁰

In the present study, receiver operator characteristic analysis identified an optimal cutoff value at 12.5 days; however, with an area under the curve of 0.55, 95% CI, 0.51–0.59, the predictive performance was not robust, indicating a need for further investigation into the optimal duration of the blanking period following CBA.

5 | LIMITATIONS

Our study has several limitations. First, being a retrospective observational study, the conclusions drawn may be influenced by unmeasured confounders. Second, our analysis did not consider the use of antiarrhythmic drugs during the follow-up period, which could potentially affect outcomes. Nevertheless, it is pertinent to acknowledge that all patients were consistently monitored postablation, adhering to current guidelines and the standard care practice of each hospital. Hence, the lack of data on antiarrhythmic drug usage is unlikely to significantly skew the assessment of the primary study outcome. The third limitation is our registry's failure to distinguish between types of ERAT—namely, AF, atrial flutter, or atrial tachycardia—which could have varying impacts on LRAT. Fourth, in this study, both ERAT and LRAT were defined as lasting more than 30 s, detected using 12-lead ECGs, Holter monitoring, and single-lead patch monitors. Patients with ERAT detected by this definition may have a substantial arrhythmia burden, potentially linked to LRAT. Consequently, these methods might not detect patients with brief atrial arrhythmic events. Fifth, another limitation of our study is the potential selection bias in patients undergoing CTI ablation, which might affect the applicability of our results to the different AF populations with atrial arrhythmias other than AF. For a detailed discussion on procedural adaptations and their outcomes, we refer readers to related studies, such as the one recently published in this cohort.²⁹ Also, the Supporting Information S1: Figure 1, which demonstrated that the role of ERAT was the same in patients undergoing CTI ablation or not, supports our analysis. Finally, the multicenter design of the study introduces heterogeneity, including differences in procedural success rates and follow-up methodology. Although detailed information on the specific follow-up methods used for each patient is lacking, all involved centers are tertiary institutes that employ standardized care approaches for rhythm monitoring and follow-up strategies according to current guidelines. This uniform approach across participating centers likely ensures consistent detection of asymptomatic recurrences across the extensive patient cohort.

6 | CONCLUSION

In conclusion, the presence of ERAT following CBA serves as a significant predictor of subsequent LRAT. This elevated risk associated with ERAT calls into question the traditional view of these early recurrences as transient and inconsequential. Our findings

necessitate a reassessment of the current clinical approach to the blanking period after CBA in patients with AF.

AUTHOR CONTRIBUTIONS

Jinsun Park: Writing—original draft preparation and editing; formal analysis; data curation. Myung-Jin Cha and Chang Hee Kwon: Conceptualization; supervision; writing—original draft preparation and editing; review and editing; methodology. Min Soo Cho, Gi-Byoung Nam, Il-Young Oh, So-Ryoung Lee, Ju Youn Kim, Sung Ho Lee, Junbeom Park, Ki-Hun Kim, Pil-Sung Yang, Jun Hyung Kim, Jaemin Shim, Hong Euy Lim: Validation; data curation.

ACKNOWLEDGMENTS

This study was supported by a grant from the Korean Heart Rhythm Society (KHRS 2021-3).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Park J, Cha M-J, Kwon CH, et al. Long-term clinical impact of early recurrence of atrial tachyarrhythmia after cryoballoon ablation in patients with atrial fibrillation. *J Cardiovasc Electrophysiol*. 2024;35:1614-1623. doi:10.1111/jce.16334