

# Catheter Ablation in Atrial Fibrillation Complicating Acute Decompensated Heart Failure: A Retrospective Cohort Study

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## Abstract

Outcomes for acute decompensated heart failure (ADHF) in the presence of atrial fibrillation (AF) have historically been unfavorable. The current investigation sought to determine whether catheter ablation (CA) could improve clinical outcomes in individuals with both conditions. A retrospective review was conducted of all ADHF cases involving AF that required admission to our hospital during 2007 through 2017. The analysis ultimately incorporated 472 patients, who were monitored for a mean duration of  $32.8 \pm 32.9$  months. Event-free survival (defined as freedom from cardiovascular death or heart failure hospitalization) stood at 61.4% after five years and declined to 42.7% by ten years. Patients who suffered events differed from those who did not in several respects: they tended to be older ( $72.1 \pm 11.0$  years versus  $68.8 \pm 13.4$  years,  $P = 0.008$ ) and were more likely to fall into Clinical Scenario 3 (24% versus 12%,  $P = 0.001$ ). In addition, the event group showed markedly lower maintenance of sinus rhythm (17% versus 31%,  $P < 0.001$ ) and underwent CA far less frequently (9% versus 21%,  $P = 0.003$ ). Those treated with CA consistently achieved better event-free survival than their untreated counterparts, with the benefit persisting after adjustment for baseline differences through matching (log-rank test:  $P < 0.001$ ). The emergence of AF at initial presentation of ADHF was associated with a generally unfavorable long-term prognosis. However, CA offered encouraging potential to improve prognosis in appropriately selected patients from this challenging population.

**Keywords:** Atrial fibrillation, Catheter ablation, Acute decompensated heart failure, Heart failure

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## Introduction

Heart failure (HF) and atrial fibrillation (AF) interact in ways that worsen patient prognosis [1, 2]. Large randomized trials conducted from the 1990s into the early 2000s, focusing on angiotensin-converting enzyme (ACE) inhibitors, beta-blockers, and mineralocorticoid receptor antagonists (MRAs), first demonstrated meaningful survival gains in HF with reduced ejection fraction (HFrEF). Subsequent studies from the late 2010s onward,

which tested angiotensin receptor–neprilysin inhibitors and sodium–glucose cotransporter 2 (SGLT2) inhibitors, have produced even greater advances in long-term outcomes [3-8]. SGLT2 inhibitors have also extended these benefits to HF with preserved ejection fraction (HFpEF), thereby widening the range of effective drug-based options for that subtype [9, 10]. Even with such pharmacological progress, however, survival after the initial diagnosis of HF often remains limited.

The frequent overlap between HF and AF raises special concern because each condition tends to promote and intensify the other [11]. Regardless of whether left ventricular function is reduced or preserved, the addition of AF reliably predicts poorer HF outcomes [2]. Effective strategies for handling this dual pathology have therefore become a major clinical priority. Since Marrouche *et al.* [12] published the CASTLE-AF trial, catheter ablation (CA) has drawn growing attention as a possible intervention for AF occurring alongside HF. Yet results from later trials concerning major clinical endpoints have not been uniform, leaving open the question of exactly which patients stand to gain the most from timely ablation. AF is documented to accompany 20% to 35% of acute decompensated heart failure (ADHF) admissions [13, 14]. On this basis, our study tested the hypothesis that CA would prove useful in the specific setting of ADHF complicated by AF.

We primarily aimed to describe the profile of patients who present with both ADHF and AF, pinpointing those features most strongly associated with cardiovascular mortality or recurrent HF hospitalization. A secondary aim was to gauge the value of CA by contrasting event-free survival in ablated patients against that observed in a well-matched comparison group.

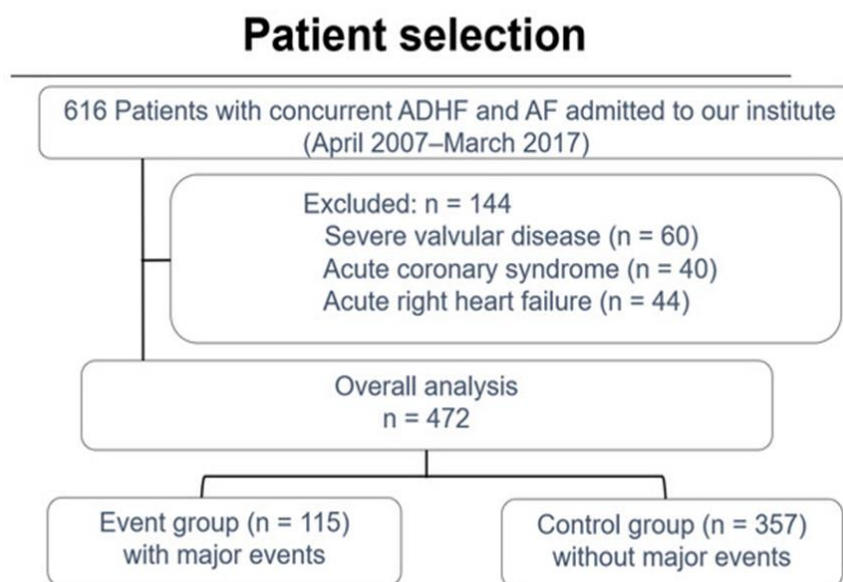
## Materials and Methods

### Patient selection and exclusion criteria

Records were consecutively drawn from the institutional database at the International Medical Center of Saitama Medical University in Japan for the interval April 2007 to March 2017. This process identified 616 patients older than 20 years who had been hospitalized for ADHF and showed AF (or atrial flutter) upon admission.

ADHF was understood as an abrupt or rapidly worsening set of symptoms and clinical signs triggered by sudden loss of effective cardiac pumping due to underlying structural heart disease. Patient categorization relied on the clinical scenario (CS) framework presented in the JCS 2017/JHFS 2017 Guideline on Diagnosis and Treatment of Acute and Chronic Heart Failure [15, 16]. The system groups ADHF cases by hemodynamic status as reflected in systolic blood pressure (CS1: above 140 mmHg; CS2: 100–140 mmHg; CS3: below 100 mmHg) and suggests tailored early management steps for each group. All relevant patient information was extracted directly from medical charts and independently reviewed by a second physician to reduce the risk of selection bias. Study details were posted online, allowing every participant to confirm their inclusion.

Patients were excluded if they had severe valvular disease that required other priority interventions instead of ablation, if they belonged to CS4 or CS5 categories (encompassing acute coronary syndrome or predominant right heart failure), or if they declined participation. Application of these rules resulted in a final cohort of 472 patients for detailed analysis (**Figure 1**).



**Figure 1.** Flow diagram illustrating patient eligibility criteria. Abbreviations: ADHF = acute decompensated heart failure; AF = atrial fibrillation.

### Data collection, follow-up, and clinical outcomes

Baseline patient information was collected on several key factors, including age, gender, admission vital signs, clinical scenario (CS) category, New York Heart Association (NYHA) functional class, and CHADS2

score. Details regarding the cause of heart disease, accompanying illnesses, laboratory test results, echocardiographic parameters, and drug therapies (including renin–angiotensin system inhibitors, mineralocorticoid receptor antagonists, antiarrhythmic

drugs, beta-blockers, and diuretics) were also recorded. Rates of freedom from major adverse events and the variables predicting those events were examined. Major events were defined as the composite endpoint of cardiovascular mortality or heart failure hospital readmission. Comparisons of patient profiles were made between the group that experienced these major events (event group) and the group that remained event-free (control group). The duration of follow-up was left to the treating physician's judgment in each case.

### *Procedure setting*

All catheter ablation procedures were conducted exclusively by five experienced electrophysiologists who had received official certification from the Japanese Heart Rhythm Society. Except for amiodarone, every antiarrhythmic medication was withheld for a minimum of five half-lives before the intervention. During the procedure, intravenous sedation was titrated to achieve and maintain a Richmond Agitation Sedation Scale score ranging from  $-3$  to  $-4$ . Once venous access was established, unfractionated heparin was administered intravenously to sustain an activated clotting time between 300 and 350 seconds. An 8-Fr 20-pole mapping catheter was advanced into the coronary sinus and/or right ventricle via the internal jugular, subclavian, or femoral vein approach. These diagnostic catheters were removed before transseptal puncture was performed using the Brockenbrough technique to enter the left atrium.

AF ablation was guided by the CARTO® three-dimensional electroanatomic mapping system (Biosense Webster, Irvine, CA, USA). The cornerstone of the ablation strategy was electrical isolation of the pulmonary veins together with ablation of the cavotricuspid isthmus. Depending on the operator's assessment, supplementary ablation targets were added, including the creation of linear lesions to target complex fractionated atrial electrograms, isolating the posterior left atrial wall, or eliminating triggers originating outside the pulmonary veins.

From 2007 to 2012, a non-irrigated ablation catheter was utilized. Between 2013 and 2014, an irrigated catheter without contact force measurement was employed. Starting in 2015, an irrigated catheter equipped with contact force sensing was used.

### *Statistical analysis*

Normally distributed continuous variables were compared between groups with the unpaired t-test, while non-normally distributed variables were analyzed using the Mann–Whitney U test. The Shapiro–Wilk test was used to evaluate whether the data followed a normal distribution. The  $\chi^2$  test was used to assess differences in categorical

variables. Event-free survival probabilities were estimated using the Kaplan–Meier product-limit method. Statistical significance was defined as a two-sided p-value less than 0.05. To identify independent predictors of major events, Cox proportional hazards regression modeling was applied, with candidate variables selected from those that reached significance in univariate screening.

Propensity score matching was implemented to balance potential confounders between treated and untreated patients. For each individual, a propensity score was calculated via logistic regression, with receipt of catheter ablation as the dependent variable and all pertinent baseline characteristics as independent variables. After matching, group balance was verified by computing standardized mean differences (SMDs) for each covariate; an SMD below 0.1 was considered sufficient balance. This approach yielded a matched cohort with well-balanced baseline features, enabling more reliable comparisons of outcomes.

In the matched dataset, continuous variables were compared again using t-tests, and categorical variables were compared using the  $\chi^2$  test. Event-free survival was illustrated with Kaplan–Meier curves, and differences between the matched treatment and control groups were evaluated using the log-rank test. All statistical computations were executed with SPSS software, version 21 (IBM Corp., Armonk, NY, USA).

## **Results and Discussion**

The overall mean follow-up time in the study population was  $32.8 \pm 32.9$  months. **Table 1** presents the baseline profile of individuals hospitalized for acute decompensated heart failure (ADHF) along with simultaneous atrial fibrillation (AF); atrial flutter was the initial rhythm in 8% of cases. The average age was  $69.5 \pm 13.0$  years, and males accounted for 57% ( $n = 274$ ) of the cohort. Mean CHADS2 score stood at  $2.2 \pm 1.2$ , while the average NYHA class was  $3.6 \pm 0.6$ . Clinical scenario distribution was as follows: CS1 in 40% ( $n = 191$ ), CS2 in 45% ( $n = 210$ ), and CS3 in 15% ( $n = 71$ ). Mean left ventricular ejection fraction (LVEF) measured  $41.5\% \pm 19.3\%$ , with the breakdown showing HF<sub>r</sub>EF in 58% ( $n = 281$ ), heart failure with mid-range ejection fraction (HF<sub>mr</sub>EF) in 15% ( $n = 73$ ), and heart failure with preserved ejection fraction (HF<sub>p</sub>EF) in 25% ( $n = 118$ ). Average left atrial diameter (LAD) was  $45.2 \pm 9.1$  mm, mean serum creatinine concentration reached  $1.5 \pm 3.3$  mg/dL, and mean brain natriuretic peptide (BNP) level was  $744.2 \pm 732.8$  pg/mL — values that exceeded standard reference ranges. Chronic kidney disease (CKD) emerged as one of the most frequent comorbidities, observed in 28% ( $n = 133$ ) of patients.

**Table 1.** Patients’ characteristics.

Baseline characteristics and clinical findings				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Overall (n = 472)
Male sex	0.116 (NS)	200 (56%)	74 (64%)	274 (57%)
Age (years)	0.008	68.8 ± 13.4	72.1 ± 11.0	69.5 ± 13.0
CHADS2 score	0.073 (NS)	2.2 ± 1.2	2.4 ± 1.3	2.2 ± 1.2
NYHA class	< 0.001	3.6 ± 0.6	3.8 ± 0.4	3.6 ± 0.6
Body mass index (BMI)	0.221 (NS)	22.3 ± 4.6	21.2 ± 3.5	21.9 ± 3.5
Systolic blood pressure (mmHg)	0.565 (NS)	135.6 ± 36.6	132.0 ± 37.3	134.1 ± 36.0
Heart rate (bpm)	0.364 (NS)	110.3 ± 35.2	105.1 ± 37.2	111.9 ± 36.8
Clinical categories				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Overall (n = 472)
CS1	0.580 (NS)	147 (30%)	44 (38%)	191 (40%)
CS2	0.078 (NS)	167 (47%)	43 (37%)	210 (44%)
CS3	0.001	43 (12%)	28 (24%)	71 (15%)
HFrEF	0.590 (NS)	215 (65%)	66 (64%)	281 (58%)
HFmrEF	0.409 (NS)	58 (18%)	15 (15%)	73 (15%)
HFpEF	0.194 (NS)	84 (24%)	34 (30%)	118 (24%)
Diagnostic/Laboratory measurements				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Overall (n = 472)
LVEF (%)	0.531 (NS)	41.4 ± 18.5	42.9 ± 21.8	41.5 ± 19.3
LVESV (mL)	0.031	70.4 ± 42.5	83.8 ± 55.3	73.6 ± 48.4
LAD (mm)	0.003	44.8 ± 8.4	48.2 ± 10.2	45.2 ± 9.1
Creatinine (mg/dL)	0.532 (NS)	1.6 ± 3.8	1.4 ± 1.2	1.5 ± 3.3
Hemoglobin (g/dL)	0.168 (NS)	14.2 ± 21.9	12.4 ± 2.3	12.9 ± 2.5
BNP (pg/mL)	0.905 (NS)	748.4 ± 756.3	758.7 ± 703.1	744.2 ± 732.8
Diagnostic/Laboratory measurements				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Overall (n = 472)
Paroxysmal atrial fibrillation (PAF)	0.116 (NS)	77 (22%)	33 (33%)	110 (23%)
Diabetes mellitus (DM)	0.056 (NS)	56 (16%)	27 (23%)	83 (18%)
Hypertension (HT)	0.916 (NS)	151 (42%)	48 (42%)	199 (42%)
Cerebrovascular disease (CVD)	0.151 (NS)	46 (13%)	21 (18%)	67 (14%)
Coronary artery disease (CAD)	< 0.001	34 (10%)	24 (21%)	58 (12%)
Chronic kidney disease (CKD)	0.040	92 (26%)	41 (36%)	133 (28%)

Values are expressed either as the number of patients (with the corresponding percentage) or as mean ± standard deviation. The following abbreviations are used: NYHA stands for New York Heart Association, BMI for body mass index, BP for blood pressure, HR for heart rate, CS for clinical scenario, HFrEF for heart failure with reduced ejection fraction, HFmrEF for heart failure with mid-range ejection fraction, HFpEF for heart failure with preserved ejection fraction, LVEF for left ventricular ejection fraction, LVESV for left ventricular end-systolic volume, LAD for left atrial diameter, Cr for serum creatinine, Hb for hemoglobin, BNP for serum brain natriuretic peptide, PAF for paroxysmal atrial fibrillation, DM for diabetes mellitus, HT for hypertension, CVD for cerebrovascular

disease, CAD for coronary artery disease, CKD for chronic kidney disease, and NS for not significant. When comparing patients who experienced major events with those who did not, the event group was older on average (72.1 ± 11.0 versus 68.8 ± 13.4 years, P = 0.008) and presented with a worse NYHA functional class (3.8 ± 0.4 versus 3.6 ± 0.6, P < 0.001). A substantially larger fraction of the event group fell into NYHA Class 3 heart failure (23% versus 12%, P = 0.004). They also had greater left ventricular end-systolic volume (LVESV) (83.8 ± 55.3 versus 70.4 ± 42.5 mL, P = 0.031) and enlarged left atrial diameter (LAD) (48.2 ± 10.2 versus 44.8 ± 8.4 mm, P = 0.003). Coronary artery disease (CAD) and chronic kidney disease (CKD) were notably more common in the event

group (CAD: 21% versus 10%,  $P < 0.001$ ; CKD: 36% versus 26%,  $P = 0.040$ ).

**Table 2** summarizes information recorded throughout the observation period. Individuals in the event group required more admissions for heart failure than those in the control group ( $1.8 \pm 1.9$  versus  $1.2 \pm 0.6$ ,  $P = 0.002$ ). At the latest assessment, the event group showed reduced left ventricular ejection fraction (LVEF) along with increased LVESV and LAD compared with the control group (latest LVEF:  $42.0\% \pm 17.8\%$  versus  $51.9\% \pm 15.1\%$ ,  $P < 0.001$ ; latest LVESV:  $91.4 \pm 50.2$  versus  $50.7 \pm 28.0$  mL,  $P <$

$0.001$ ; latest LAD:  $49.5 \pm 9.1$  versus  $45.5 \pm 8.4$  mm,  $P = 0.006$ ). Sinus rhythm (SR) was maintained less often in the event group on the final visit (17% versus 31%,  $P < 0.001$ ), and fewer patients in this group had undergone catheter ablation (CA) (9% versus 21%,  $P = 0.003$ ). Heart failure drug prescriptions were generally comparable across groups, except for a higher rate of diuretic use in the event group (72% versus 60%,  $P = 0.018$ ). Oral anticoagulant therapy remained infrequent overall, staying below 50% even among patients managed before direct oral anticoagulants (DOACs) became widely available.

**Table 2.** Data were analyzed during the study period.

Heart failure hospitalization, cardiac function, procedures, and medications				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Total (n = 472)
Single HF hospitalization	0.015	246 (69%)	65 (57%)	311 (57%)
Multiple HF hospitalizations	0.015	111 (31%)	50 (43%)	161 (34%)
Total number of HF hospitalizations	0.002	$1.2 \pm 0.6$	$1.8 \pm 1.9$	$1.3 \pm 1.1$
Latest LVEF (%)	<0.001	$51.9 \pm 15.1$	$42.0 \pm 17.8$	$48.7 \pm 16.7$
Latest LVESV (mL)	<0.001	$50.7 \pm 28.0$	$91.4 \pm 50.2$	$63.8 \pm 50.2$
Latest LAD (mm)	0.006	$45.5 \pm 8.4$	$49.5 \pm 9.1$	$46.8 \pm 9.1$
Sinus rhythm maintenance	<0.001	111 (31%)	20 (17%)	131 (28%)
Interventional Procedures				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Total (n = 472)
Catheter ablation (CA)	0.003	74 (21%)	10 (9%)	84 (17%)
<sup>L</sup> Before the contact force era	0.373 (NS)	62 (18%)	8 (7%)	70 (14%)
<sup>L</sup> After the contact force era	0.373 (NS)	12 (3%)	2 (2%)	14 (3%)
Pacemaker implantation	0.675 (NS)	7 (2%)	3 (3%)	10 (2%)
Implantable cardioverter-defibrillator (ICD)	0.134 (NS)	13 (4%)	8 (7%)	21 (4%)
Cardiac resynchronization therapy (CRT)	0.041	8 (2%)	7 (6%)	15 (3%)
Other interventions	0.066 (NS)	9 (3%)	7 (6%)	16 (3%)
Pharmacological treatment				
Variable	P-value	Control group (n = 357)	Event group (n = 115)	Total (n = 472)
Antiplatelet therapy	0.795 (NS)	98 (27%)	33 (29%)	131 (28%)
Oral anticoagulants (OAC)	0.580 (NS)	172 (48%) [DOAC 17%]	52 (45%) [DOAC 13%]	224 (47%) [DOAC 16%]
Beta-blockers (BB)	0.443 (NS)	173 (48%)	51 (45%)	224 (47%)
RAAS inhibitors	0.474 (NS)	185 (52%)	64 (56%)	249 (52%)
Antiarrhythmic drugs (AAD)	0.980 (NS)	120 (34%)	36 (31%)	156 (32%)
Amiodarone use	0.575 (NS)	72 (20%)	26 (23%)	98 (21%)
Diuretics	0.018	214 (60%)	83 (72%)	297 (62%)

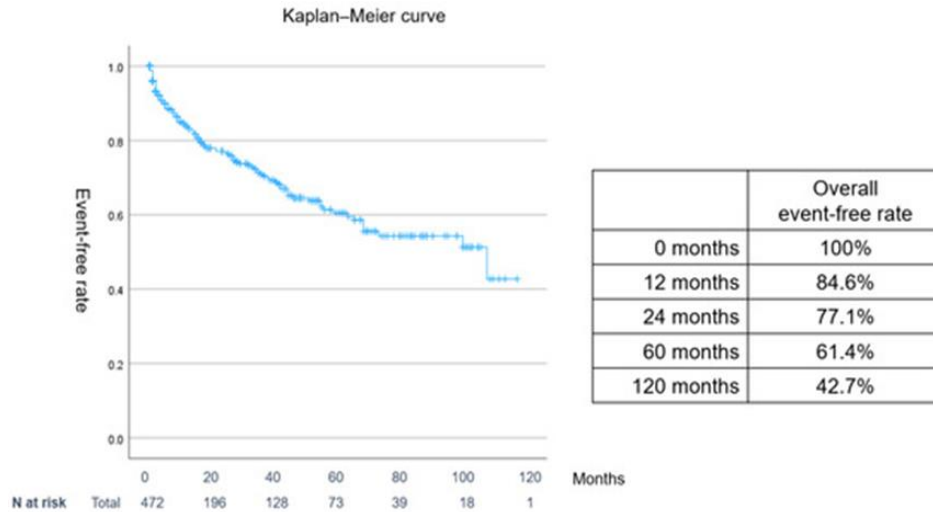
Data are presented as numbers (percentage) of patients or as mean  $\pm$  standard deviation. Abbreviations: NS = not significant, AAD = antiarrhythmic drugs, HFH = heart failure hospitalization, CRT = cardiac resynchronization

therapy, RAAS = renin–angiotensin–aldosterone system, LVEF = left ventricular ejection fraction, BB = beta-blockers, LVESV = left ventricular end-systolic volume, LAD = left atrial diameter, SR = sinus rhythm, CA =

catheter ablation, ICD = implantable cardioverter-defibrillator, OAC = oral anticoagulants, and DOAC = direct oral anticoagulants.

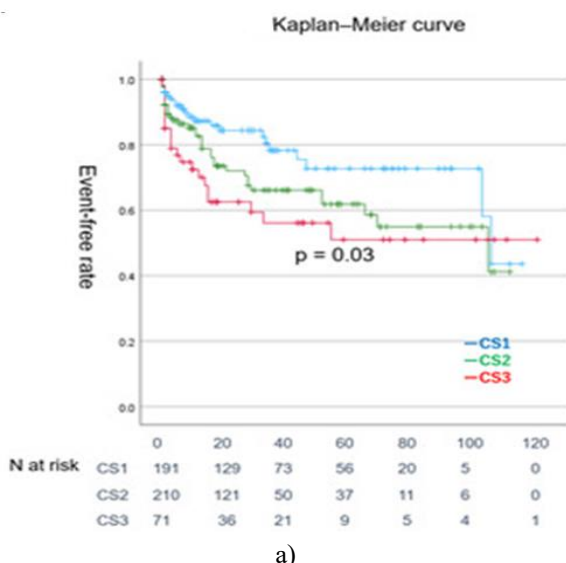
**Figure 2** presents the overall Kaplan–Meier survival curve for the complete cohort, showing freedom from events.

Freedom from events reached 84.6% at 12 months and 77.1% at 24 months. The 5-year (60-month) event-free rate was 61.4%, while the 10-year (120-month) rate dropped to 42.7%.

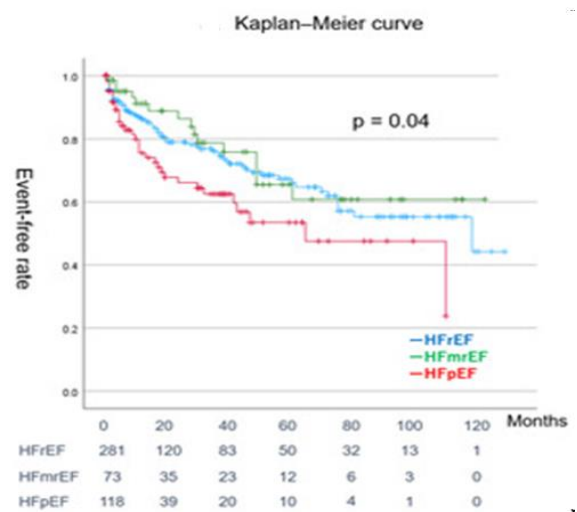


**Figure 2.** Overall event-free Kaplan–Meier curve for acute ADHF with AF. Events included cardiovascular death and hospitalization for HF. Abbreviations: ADHF = acute decompensated heart failure; AF = atrial fibrillation; CS = clinical scenario.

**Figures 3a** and **3B** display event-free survival broken down by clinical scenario (CS) category and by ejection fraction status, respectively. Patients in CS3 and those diagnosed with HF with preserved ejection fraction (HFpEF) had clearly lower event-free rates (CS3, log-rank test:  $P = 0.03$ ; HFpEF, log-rank test:  $P = 0.04$ ). No meaningful separation appeared when comparing outcomes across the HFrEF, HF with mid-range ejection fraction (HFmrEF), and HFpEF categories (log-rank test:  $P = 0.11$ ).



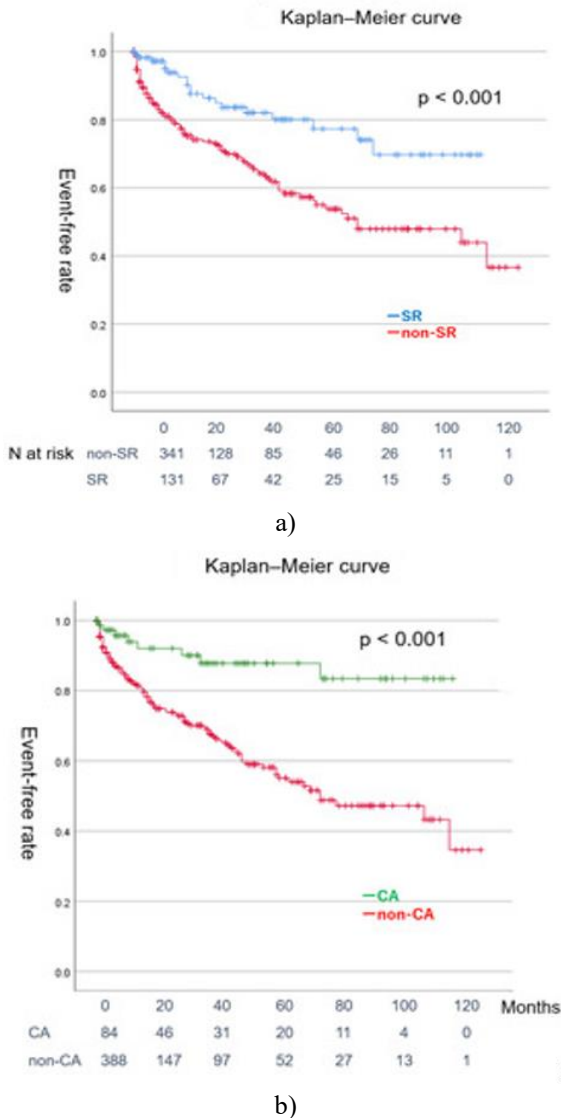
a)



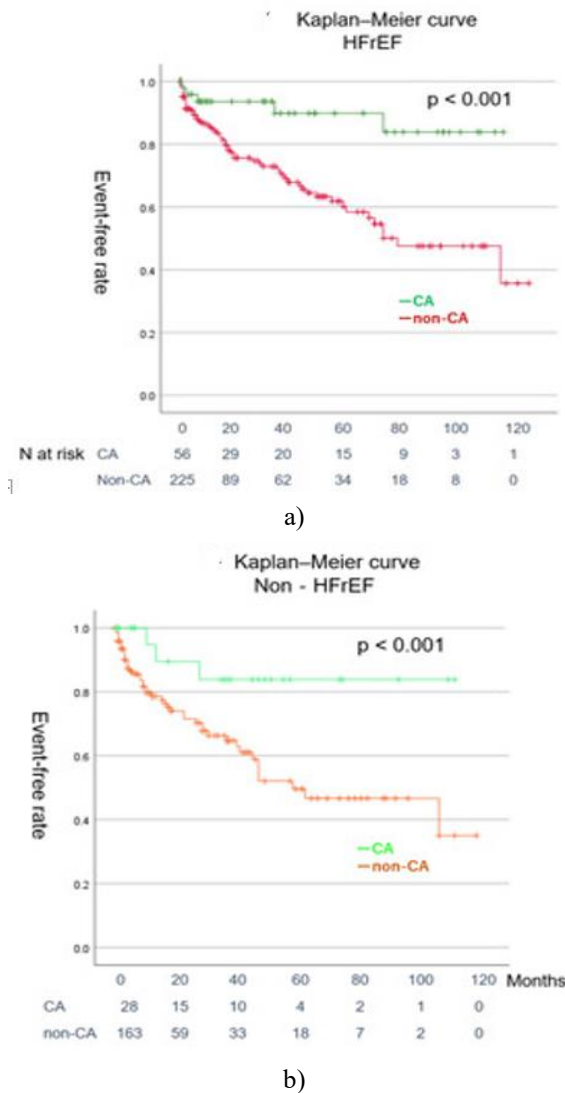
b)

**Figure 3.** Event-free Kaplan–Meier curve categorized by different criteria. CS3 showed a significantly lower event-free rate (log-rank test:  $P = 0.01$ ). (a) Blue line: CS1, green line: CS2, red line: CS3. (b) Blue line: HFrEF, green line: HFmrEF, red line: HFpEF. (a) Green line: CA in HFrEF, red line: non-CA in HFrEF. (b) Right green line: CA in non-HFrEF, orange line: non-CA in non-HFrEF. Abbreviations: CS = clinical scenario, HfrEF = heart failure with reduced ejection fraction, HfmrEF = heart failure with mid-range ejection fraction, and HfpEF = heart failure with preserved ejection fraction.

**Figure 4a** contrasts event-free survival between patients who stayed in sinus rhythm (SR) and those who did not, while **Figure 4b** compares the catheter ablation (CA) group against the non-CA group. Both sustained sinus rhythm and receipt of CA were linked to markedly superior outcomes (log-rank test:  $P < 0.001$  for each). **Figure 5** further breaks down event-free survival by CA status separately in the HFrEF and non-HFrEF subgroups. In both populations, CA was associated with a clear reduction in events (log-rank test:  $P < 0.001$  in each subgroup).



**Figure 4.** Impacts of SR maintenance and CA on event-free rate. Abbreviations: CA = catheter ablation, and SR = sinus rhythm.

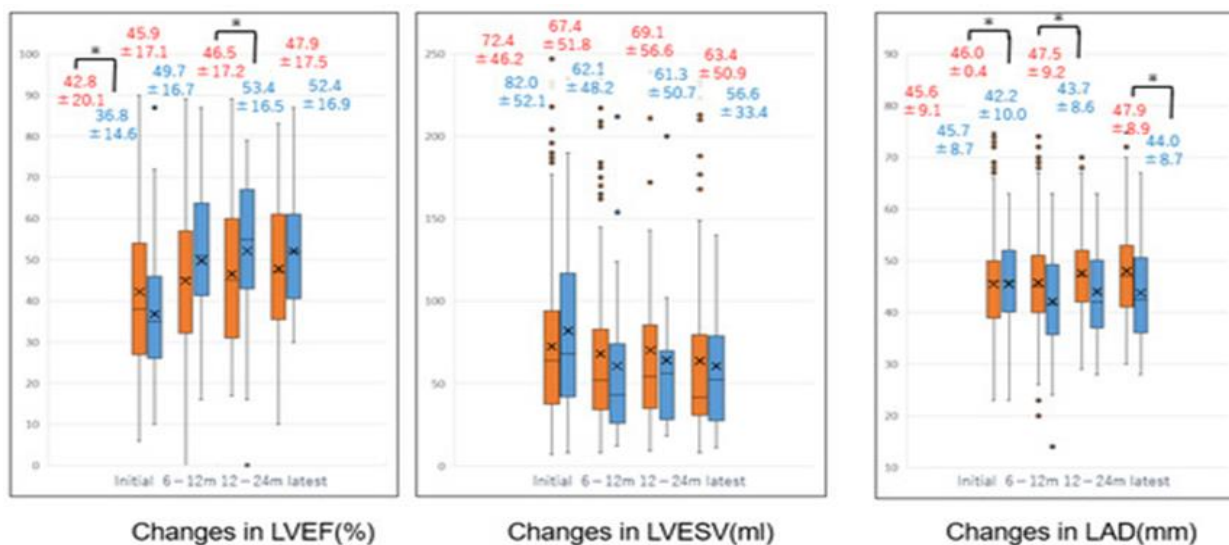


**Figure 5.** Event-free Kaplan-Meier curves for the CA and non-CA groups within the HFrEF and non-HFrEF populations.

**Figure 6** contains box plots that track changes over time in average left ventricular ejection fraction (LVEF), left ventricular end-systolic volume (LVESV), and left atrial diameter (LAD) for the CA and non-CA groups. Measurements were taken during the index hospitalization, between 6 and 12 months after discharge, between 12 and 24 months after discharge, and at the latest available visit. Blue boxes indicate the CA group, and orange boxes indicate the non-CA group. At the start, LVEF was noticeably lower in the CA group, but it exceeded that of the non-CA group by the 12–24 month mark (baseline LVEF: CA group versus non-CA group =  $36.8 \pm 14.6\%$  versus  $42.8 \pm 20.1\%$ ,  $P = 0.003$ ). LVESV tended to be smaller in the CA group from 6–12 months onward, though the difference did not achieve statistical significance. The clearest divergence occurred in LAD. Starting values were virtually the same (CA group versus non-CA group =  $45.7 \pm 8.7$  mm versus  $45.6 \pm 9.1$  mm,  $P = 1.0$ ), but LAD became significantly smaller in the CA

group at 6–12 months ( $42.2 \pm 10.0$  mm versus  $46.0 \pm 10.4$  mm,  $P = 0.008$ ), at 12–24 months ( $43.7 \pm 8.6$  mm versus

$47.5 \pm 9.2$  mm,  $P = 0.02$ ), and at the most recent follow-up ( $44.0 \pm 8.7$  mm versus  $47.9 \pm 8.9$  mm,  $P = 0.02$ ).



**Figure 6.** Time course of mean LVEF, LVESV, and LAD. The figure illustrates the time course of mean left ventricular ejection fraction (LVEF), left ventricular end-systolic volume (LVESV), and left atrial diameter (LAD) in the non-CA and CA groups at baseline, 6–12 months, 12–24 months, and the most recent follow-up. Orange box plots represent the non-CA group, while blue box plots represent the CA group. Numbers represent mean  $\pm$  standard deviation. \* indicates a significant difference between groups.

**Table 3** reports the hazard ratios associated with major events from both univariate and multivariate models. Univariate screening highlighted several baseline predictors, including NYHA Class 3 or 4 heart failure, CS3 classification, elevated LVESV and LAD, and the presence of CAD or CKD. Follow-up variables, such as

repeated heart failure admissions, CA performance, sustained sinus rhythm, and diuretic therapy, also reached significance. In the multivariate analysis, repeated hospitalizations, CA, and diuretic use remained independently associated with event risk.

**Table 3.** Event hazard ratios from the univariate and multivariate analyses.

Univariate and multivariate hazard ratio analysis						
Variable	Multivariate HR	P-value	95% CI	Univariate HR	P-value	95% CI
<b>Baseline characteristics</b>						
Age > 74 years	—	—	—	1.20	0.403	(0.78–1.83)
NYHA class III/IV	—	—	—	1.53	0.070	(0.97–2.43)
CS class 3	—	—	—	2.20	0.004	(1.28–3.75)
LVEF < 40%	—	—	—	0.75	0.180	(0.50–1.14)
LVESV > 84 mL	—	—	—	1.85	0.003	(1.25–2.80)
LAD > 44 mm	—	—	—	1.74	0.012	(1.13–2.69)
Coronary artery disease (CAD)	—	—	—	2.53	0.002	(1.42–4.53)
Chronic kidney disease (CKD)	—	—	—	1.66	0.036	(1.04–2.67)
<b>Follow-up variables</b>						
Variable	Multivariate HR	p-value	95% CI	Univariate HR	p-value	95% CI
Multiple hospitalizations	2.26	<0.001	(1.41–3.61)	4.53	<0.001	(2.60–7.91)
Catheter ablation (CA)	0.41	0.012	(0.21–0.82)	0.36	0.004	(0.18–0.71)
Sinus rhythm maintenance	—	—	—	0.46	0.004	(0.27–0.78)

Diuretics use 2.20 0.005 (1.27–3.80) 3.02 <0.001 (1.69–5.41)

Abbreviations: SR = sinus rhythm, HR = hazard ratio, LVESV = left ventricular end-systolic volume, CA = catheter ablation, CI = 95% confidence interval, NYHA = New York Heart Association, CKD = chronic kidney disease, CS = clinical scenario, LVEF = left ventricular ejection fraction, LAD = left atrial diameter, and CAD = coronary artery disease.

**Table 4** outlines the features of patients in the propensity-matched CA and non-CA groups before and after matching. Once matching was completed, the two groups became comparable with respect to age, gender, NYHA functional class, CHADS2 score, LVEF, and LAD. Before matching, those who underwent CA tended to be younger, had lower CHADS2 scores and milder NYHA classes, had lower BNP concentrations, and showed lower LVEF values than the non-CA patients. The variables selected for matching included age, sex, CHADS2 score, NYHA classification, LVEF, and LAD, since earlier investigations had highlighted these as key indicators of a

poorer prognosis in patients with both AF and HF [17-20]. In the matched cohort, the CA group displayed notable gains in LVEF, reductions in LAD size, and declines in BNP levels. Arrhythmia recurrence affected 35% (n = 17) of patients in the CA group, and 31% (n = 12) required a second ablation session. Sinus rhythm (SR) was preserved far more often in the matched CA group compared with the matched non-CA group (73% versus 33%, P < 0.001). Overall, CA produced a clear improvement in LVEF and led to meaningful reductions in both LAD and circulating BNP concentrations.

**Table 4.** Comparison of patient characteristics between the CA group and the non-CA group pre- and post-matching.

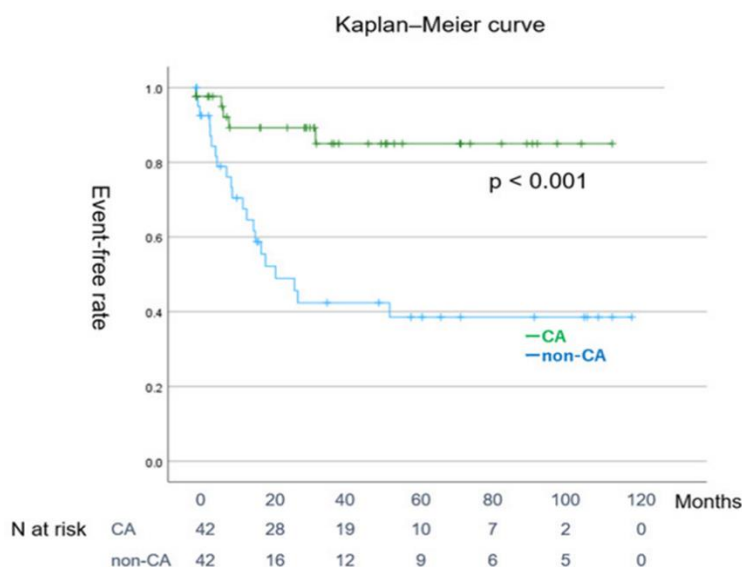
Pre-matching cohort			
Variable	P-value	Non-CA group (n = 388)	CA group (n = 84)
Age (years)	< 0.001	66.2 ± 11.2	61.5 ± 13.0
Male sex	0.440 (NS)	218 (56%)	56 (67%)
CHADS2 score	< 0.001	2.3 ± 1.2	1.6 ± 1.0
NYHA class	< 0.001	3.7 ± 0.5	3.2 ± 0.6
Pre-procedure LVEF (%)	0.003	42.8 ± 20.1	36.8 ± 14.6
Latest LVEF (%)	0.225 (NS)	47.7 ± 17.2	50.9 ± 15.4
Pre-procedure LAD (mm)	0.951 (NS)	45.6 ± 9.1	45.7 ± 8.7
Latest LAD (mm)	0.009	47.9 ± 8.9	43.8 ± 9.3
Pre-procedure BNP (pg/mL)	0.005	787.7 ± 777.5	567.5 ± 511.2
Latest BNP (pg/mL)	< 0.001	1041.0 ± 4870.1	71.6 ± 87.0
Recurrence after the first CA	NA	NA	48 (57%)
Second ablation	NA	NA	27 (32%)
Sinus rhythm maintenance	< 0.001	77 (20%)	54 (64%)
Post-Matching Cohort			
Variable	P-value	Non-CA group (n = 42)	CA group (n = 42)
Age (years)	0.110 (NS)	66.2 ± 11.2	60.3 ± 11.3
Male sex	0.440 (NS)	34 (70%)	30 (62%)
CHADS2 score	0.790 (NS)	1.5 ± 1.0	1.6 ± 0.8
NYHA class	0.340 (NS)	2.8 ± 0.8	2.4 ± 1.0
Pre-procedure LVEF (%)	0.470 (NS)	40.0 ± 17.0	35.6 ± 15.9
Latest LVEF (%)	< 0.001	43.9 ± 18.5	59.1 ± 13.8
Pre-procedure LAD (mm)	0.230 (NS)	44.2 ± 11.2	44.3 ± 9.2
Latest LAD (mm)	0.047	49.1 ± 13.5	42.1 ± 13.8
Pre-procedure BNP (pg/mL)	0.070 (NS)	713.2 ± 722.6	463.1 ± 407.4
Latest BNP (pg/mL)	< 0.001	671.9 ± 806.2	71.6 ± 87.0

Recurrence after the first CA	NA	NA	17 (40%)
Second ablation	NA	NA	13 (31%)
Sinus rhythm maintenance	< 0.001	14 (33%)	31 (73%)

Age, sex, CHADS2 score, NYHA classification, LVEF, and LAD have been identified in a previous study as poor prognostic factors for HF and AF. After matching, the analysis compared 42 matched cases. Data are presented as the number (percentage) of patients or as mean ± standard deviation. Abbreviations: NA = not applicable, NS = not significant, CA = catheter ablation, LAD = left

atrial diameter, NYHA = New York Heart Association, LVEF = left ventricular ejection fraction, SR = sinus rhythm, and BNP = serum brain natriuretic peptide.

**Figure 7** demonstrates that the matched CA group achieved a substantially better event-free survival than the matched non-CA group (log-rank test:  $P < 0.001$ ).



**Figure 7.** Event-free Kaplan–Meier curve for the CA and non-CA groups after matching. Abbreviation: CA = catheter ablation.

*Major findings*

The present retrospective analysis uncovered several noteworthy observations. First, individuals who encountered major events—defined as cardiovascular death or heart failure hospitalization—tended to be older, were more frequently male, and carried higher CHADS2 scores. Baseline measures of heart function did not differ markedly between the event and control groups; however, the event group displayed larger LVESV and LAD. They also showed increased rates of coronary artery disease (CAD) and chronic kidney disease (CKD) as accompanying illnesses.

Second, the overall outlook remained unfavorable for patients admitted with acute decompensated heart failure (ADHF) who had atrial fibrillation (AF) at presentation. Event-free survival was 61.4% after 5 years and 42.7% after 10 years. Event rates rose sharply in the CS3 category. When stratified by ejection fraction type, the HF with preserved ejection fraction (HFpEF) subgroup experienced the highest event rate. In contrast, differences across HF rEF, HF with mid-range ejection fraction

(HFmrEF), and HFpEF did not reach statistical significance.

Third, throughout the follow-up interval, the event group faced more repeated heart failure admissions, showed progressive decline in cardiac performance, and developed adverse structural changes in both the left ventricle and left atrium. In comparison, the control group maintained sinus rhythm (SR) at a higher rate and underwent catheter ablation (CA) more frequently. Background heart failure medications were largely similar between groups, yet diuretic prescriptions were used significantly more often in the event group.

Finally, successful maintenance of sinus rhythm and performance of CA correlated with better-preserved cardiac function, lower BNP levels, and a superior long-term prognosis. CA additionally appeared to slow or prevent unfavorable remodeling, most prominently in the left atrium. These benefits persisted after balancing patient backgrounds via propensity score matching.

*Relationship between AF and HF: complexity of atrial fibrillation and heart failure*

Beginning in the 1990s, important medical advances—particularly the adoption of ACE inhibitors, beta-blockers, and mineralocorticoid receptor antagonists (MRAs)—led to clear survival gains in HF with reduced ejection fraction (HFrEF) [3-5]. In more recent years, emphasis has shifted toward the “fantastic four” regimen, which includes angiotensin receptor–neprilysin inhibitors (replacing traditional ACE inhibitors) and sodium–glucose cotransporter 2 (SGLT2) inhibitors [15]. Nevertheless, achieving broad improvements in heart failure prognosis has remained difficult. Contributing factors include the large share of cases classified as HF with preserved ejection fraction (HFpEF), which makes up nearly half of all HF patients, the scarcity of proven treatments for this subtype, and persistently elevated rates of sudden worsening and rehospitalization in acute decompensated heart failure (ADHF) [16, 17].

Atrial fibrillation develops more commonly in individuals with heart failure than in those without, and the presence of AF raises the future risk of developing heart failure [18]. At the same time, numerous reports have documented high success rates in restoring and maintaining sinus rhythm through catheter ablation, with comparable benefits noted even when HF and AF coexist [11, 19].

Although the number of participants was limited, our earlier investigation indicated that performing AF ablation in patients with HFrEF restored both left ventricular and left atrial function. This result aligns with findings from multiple systematic reviews [20, 21]. Nevertheless, whether this approach could influence hard clinical endpoints, such as heart failure hospitalization or cardiovascular death, remained uncertain until the 2018 CASTLE-AF trial, which reported favorable outcomes of CA among AF patients with an implantable cardioverter-defibrillator (ICD) or cardiac resynchronization therapy-defibrillator (CRTD) [12].

Even though some encouraging results emerged, the benefits of AF ablation appeared weaker in the CASTLE-AF trial for individuals with more advanced heart failure, including those with LVEF below 25% or NYHA Class 3 symptoms. Identifying the specific heart failure subtypes that derive the greatest advantage from AF ablation remains an important unresolved question [22, 23].

Despite substantial progress in heart failure medications in recent years, especially the adoption of the so-called “Fantastic Four” combination, overall survival rates for heart failure have shown little meaningful change over the last several decades [21]. A key reason for this stagnation is the persistently unfavorable outlook seen in acute decompensated heart failure (ADHF) when it occurs together with atrial fibrillation (AF) [22, 23]. Standard drug-based treatments tend to have restricted effectiveness in heart failure patients who also have AF, and the ideal

heart rate goal during rate-control therapy differs from the target used in patients who remain in sinus rhythm [24]. In addition, beta-blockers — which usually serve as a cornerstone for both heart failure treatment and rate control — show diminished impact in this combined condition, making it difficult to achieve and sustain sinus rhythm using medications by themselves [25].

Strong supporting data now exist for applying CA across the spectrum of heart failure with AF, ranging from HFrEF to HFpEF, as evidenced by multiple trials including CASTLE-AF [12, 26-29]. The 2024 EHRA/HRS/APHRS consensus document has elevated CA for heart failure accompanied by AF to a Class I recommendation [30]. Still, this procedure may not be appropriate for every patient with HF and AF, and additional work is needed to pinpoint the subgroups likely to gain the most benefit. Our investigation focused on ADHF, a condition with a guarded prognosis. Roughly 20% to 35% of ADHF cases also involve AF, and this overlap is known to worsen clinical results. The population studied in CASTLE-AF shares similarities with ours in terms of age and sex distribution. Yet, that trial did not separately examine individuals with or without a prior episode of ADHF [12]. Furthermore, patients with HFmrEF and HFpEF were excluded. In this context, the current study offers fresh insight. One earlier report found that among hospitalized patients with acute heart failure, the presence of current AF or a previous history of AF was tied to smaller improvements in shortness of breath and elevated rates of illness and death within 30 days [31]. Even so, the specific factors that drive prognosis within this particular subgroup have not been fully clarified.

Although a large proportion of HFpEF trials enroll patients with AF (32%–57%), improving treatment strategies for this group remains a priority. Angiotensin receptor–neprilysin inhibitors (ARNIs) showed some benefit in HFpEF, but the improvement did not reach statistical significance. SGLT2 inhibitors became the first medication class to demonstrate clear advantages in HFpEF. More recently, glucagon-like peptide-1 (GLP-1) receptor agonists have produced better outcomes in both HFrEF and HFpEF, especially among individuals with obesity [32, 33]. These agents have also shown promise in reducing the risk of AF recurrence after ablation, suggesting they could be useful in ADHF patients with AF. Unfortunately, GLP-1 receptor agonists were not available or used during the follow-up period of the present study, leaving this question for future research [34]. An analysis from the OPTIMIZE-HF trial (where 31% of participants had AF) identified several predictors of early death following discharge after ADHF admission: advancing age (hazard ratio 1.22 per 10-year increase), elevated serum creatinine (hazard ratio 1.32 per 4-mg/dL rise), reactive airway disease, liver disease, reduced

systolic blood pressure, low serum sodium, lower admission body weight, and depression [35]—in our cohort of patients with AF, older age and chronic kidney disease (CKD) stood out as indicators of worse prognosis, accompanied by a markedly higher proportion of CS3 cases. However, our study did not evaluate reactive airway disease, liver disease, or depression.

The connection between echocardiographic measurements taken in the acute phase and long-term prognosis in patients experiencing both ADHF and AF has received limited attention. Kim *et al.* [36] found that left ventricular end-diastolic diameter served as a prognostic marker in a Korean registry of ischemic heart failure patients, of whom 24.4% had AF. In the current analysis, patients in the event group presented with larger LAD and LVESV at admission than those in the control group. Clarifying what these differences mean will require deeper exploration of underlying myocardial injury and the potential for cardiac reverse remodeling.

#### *Clinical outcomes of patients with concurrent ADHF and AF during follow-up*

In this analysis, the event group experienced more frequent hospital readmissions for heart failure and required greater use of diuretics compared with the control group. Both repeated hospitalizations and increased diuretic therapy emerged as strong independent predictors of major events in the multivariate model. Prior research has consistently linked a higher number of heart failure admissions to a poorer long-term outlook in HF patients [37]. Similarly, ongoing fluid overload after initial stabilization of ADHF and extended reliance on diuretics in chronic HF have been tied to worse survival [38, 39]. The present results are consistent with these earlier observations, especially in the challenging subgroup of patients with both ADHF and AF.

Patients who underwent catheter ablation (CA) and maintained sinus rhythm (SR) at the final visit had markedly fewer major events than those who did not. A detailed review of the AFFIRM trial—which originally found no survival difference between rhythm-control and rate-control strategies in AF—revealed that individuals who successfully stayed in sinus rhythm had a clearly better prognosis [40].

Nevertheless, confirming true SR maintenance can be difficult because AF often returns without noticeable symptoms. In contrast, the CASTLE-AF trial enabled accurate tracking of AF burden by including patients with implantable cardioverter-defibrillators (ICD) or cardiac resynchronization therapy-defibrillators (CRTD). That subanalysis showed that reducing AF burden by more than 50% was associated with improved outcomes [41]. Although AF burden could not be quantified in our cohort, the findings strongly support the goal of achieving and

maintaining sinus rhythm in patients presenting with combined ADHF and AF.

Throughout the observation period, the event group maintained a larger left atrial diameter (LAD) and left ventricular end-systolic volume (LVESV) than the control group. In heart failure management—whether through medications or procedural interventions—reversal of left ventricular remodeling is widely recognized as an important marker of better prognosis. It can also promote favorable changes in the left atrium. Earlier work has confirmed that AF ablation promotes reverse remodeling in both the left ventricle and left atrium [42, 43]. The current study reinforces this pattern and particularly emphasizes the role of CA in driving left atrial reverse remodeling. Targeted treatment of the left atrium may therefore amplify the benefits of drug therapy in heart failure, functioning as an additional enhancer. Further mechanistic studies will be needed to explain this interaction fully. At a minimum, our data indicate that reverse remodeling of both the left ventricle and the left atrium is a valuable prognostic indicator in patients with concurrent ADHF and AF.

#### *Effect of CA on patients with combined ADHF and AF*

When atrial fibrillation and heart failure occur together, outcomes tend to be worse if heart failure develops first rather than when AF appears before HF [44]. However, in many episodes of acute decompensated heart failure, it is difficult to determine which condition came first, and dedicated prognostic studies focusing specifically on this overlap are scarce.

As expected, individuals in our series who presented with both ADHF and AF faced a particularly unfavorable long-term prognosis. Differences in LVEF had only a limited influence on outcomes, whereas CS3 classification was strongly associated with poorer results. Komuro *et al.* [45] previously reported worse survival linked to CS3 among Japanese patients with ADHF, in a cohort where roughly 53% had AF. Likewise, the WET-HF Registry—which also included approximately 53% of patients with AF—found that CS3 was associated with an adverse prognosis across ejection fraction categories. However, the association was somewhat weaker in HFpEF patients with CS3 [45]. Because our study excluded severe valvular disease (unlike WET-HF), the observed patterns remained broadly consistent with those earlier reports.

Since the publication of the CASTLE-AF trial [12], the role of AF ablation in patients with coexisting HF and AF has broadened considerably. Nevertheless, its specific value in the setting of ADHF combined with AF has received little direct attention.

In the present study, CA was associated with a significant improvement in prognosis for patients with ADHF and

AF, and this advantage remained robust after propensity score-matching adjustment for baseline differences. In addition, CA promoted reverse remodeling of both the left ventricle and left atrium, accompanied by a substantial drop in BNP levels. Two previous reports have described the successful use of AF ablation performed during the acute phase in ADHF patients with unstable hemodynamics [46, 47].

Sakamoto *et al.* [48] examined CA performed within 90 days of admission in a large Japanese registry of patients with combined ADHF and AF and found positive results. However, their analysis lacked a matched control group. Our findings indicate that the benefits of CA in patients with concurrent ADHF and AF persist after careful matching. Therefore, catheter ablation should be seriously considered for this high-risk population. It is worth noting that, before matching, the non-CA group was older, had higher CHADS2 and NYHA scores, yet paradoxically showed better LVEF than the CA group. This pattern suggests that clinicians may have been less likely to refer higher-risk patients with relatively preserved cardiac function for ablation.

### Clinical implication

This single-center analysis demonstrated that performing catheter ablation (CA) during hospitalization for acute decompensated heart failure (ADHF) in patients with atrial fibrillation (AF) led to a meaningful improvement in prognosis, and this advantage persisted after propensity score matching. These results highlight the possible clinical value of CA as a treatment option in this difficult patient population.

### Study limitations

As with any single-center retrospective study, several limitations must be acknowledged. Follow-up duration and intensity were decided individually by each treating physician rather than following a uniform schedule, which could have introduced bias in decisions about when to stop monitoring. To better isolate the influence of AF and CA, individuals with severe valvular disease — especially significant mitral regurgitation — were deliberately excluded. Consequently, the cohort does not represent the full spectrum of heart failure patients who also have atrial fibrillation, leaving open the possibility of selection bias. In addition, the overall sample size was too small to allow reliable three-group comparisons according to clinical scenario (CS) classification or ejection fraction categories, raising concerns about insufficient statistical power. Propensity score matching was used to balance visible differences between the CA and non-CA groups. However, only a limited set of variables was available for matching, and the risk of subjective judgment in selecting them cannot be completely ruled out.

Furthermore, patient enrollment began in 2007 and spanned 11 years, well before direct oral anticoagulants (DOACs) became standard therapy. Modern heart failure management has since evolved considerably, particularly with the introduction of the “fantastic four” approach and the proven benefits of SGLT2 inhibitors in HF with preserved ejection fraction (HFpEF). These advances, along with newer ablation technologies such as high-density mapping systems and pulsed field ablation, have made current procedures more accurate and safer. Although the techniques used in this study lag behind current standards, the observed benefits of CA remain clinically meaningful.

### Conclusion

Individuals who presented with atrial fibrillation (AF) at the initial onset of acute decompensated heart failure (ADHF) faced a generally unfavorable long-term outlook. While catheter ablation (CA) appeared promising for improving prognosis in selected cases, additional studies are needed to define better which patients should receive the highest priority for this intervention.

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