Heart Rate Decrease After Atrial Fibrillation Catheter Ablation Predicts Decompensated Heart Failure After the Procedure

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Background: Decompensated heart failure (DHF) can complicate catheter ablation for atrial fibrillation (AF). We investigated the association between heart rate and DHF in AF patients undergoing catheter ablation.

Methods and Results: In all, 1,004 consecutive patients who underwent initial ablation for AF (mean ±SD age 68±10 years; 34% female; persistent AF n=513 [51%]) were enrolled in the study. Heart rate was assessed before and after ablation. DHF was defined as heart failure requiring medical therapy within 2 days after the procedure. The incidence of DHF was 2% (22 of 1,004 patients). Patients with DHF had a higher prevalence of a history of symptomatic heart failure (11/22 [50%] vs. 160/982 [16%]; P<0.0001) and a greater degree of heart rate decrease after the procedure (−21±29 vs. 2±21 beats/min; P=0.001) than those without DHF. On multivariate analysis, heart rate decrease was a significant independent predictor of DHF (hazard ratio 0.8; 95% confidence interval 0.7–0.9; P=0.004; 10 beats/min-increment).

Conclusions: In patients undergoing AF ablation, a decrease in heart rate after the procedure was an independent predictor of DHF.

Key Words: Atrial fibrillation; Catheter ablation; Complications; Decompensated heart failure; Heart rate
Catheter Ablation Procedure

Class I antiarrhythmic agents, Class III antiarrhythmic agents, digitalis and verapamil were discontinued the day before the procedure. In contrast, β-blockers were continued during periprocedural periods.

Electrophysiological studies and catheter ablation were performed by experienced operators under intravenous sedation with propofol or dexmedetomidine. Propofol was used as the anesthetic for deep sedation with a laryngeal mask airway; dexmedetomidine was used as an anesthetic for conscious sedation. An electroanatomical mapping system (Carto 3 [Biosense Webster, Diamond Bar CA, USA], Ensite NavX [Abbott, Abbott Park IL, USA], or Rhythmia [Boston Scientific, Boston MA, USA]) was used. Radiofrequency catheter ablation was performed between October 2014 and March 2016. Between March 2016 and December 2018, cryoballoon ablation was performed for paroxysmal AF and for persistent AF in patients considered frail and at high risk of procedure-related complications. Patients with common PVs or a large PV diameter underwent radiofrequency catheter ablation. Two patients with paroxysmal AF underwent laser balloon ablation between July 2018 and September 2018.

Periprocedural intravenous fluid, usually Ringer’s acetate, was administered to prevent contrast-induced nephropathy or dehydration. Infusion volumes were 0.45 L before the procedure, 0.1 L/h during the procedure, and 1 L after the procedure. The infusion volume was reduced or avoided if hydration was contraindicated, such as in hemodialysis patients, or in other situations as per the operator’s judgment.

In radiofrequency catheter ablation, circumferential ablation around both ipsilateral PVs was performed using an open-irrigated linear ablation catheter (Thermocool SmartTouch, Thermocool SmartTouch SF, NAVISTAR Thermocool, Thermocool SF, CELSIOUS [all Biosense Webster]; or TactiCath SE, FlexAbility, via a Swartz Braided SL0 Transseptal Guiding Introducer Sheath or AGILLS™ NXT Steerable Introducer [all Abbott]). PV isolation was considered complete when the 20-pole circular catheter no longer recorded any PV potentials.

In cryoballoon ablation, a cryoballoon catheter with a 28-mm balloon (Arctic Front Advance: Medtronic, Minneapolis MN, USA) was passed into each PV under fluoroscopic guidance and/or an electroanatomical mapping system. After confirming PV occlusion by pulmonary venography, cryoablation commenced and was usually continued for 180s. The contrast medium was diluted with saline according to the operator’s judgment. Accordingly, the precise amount of contrast medium was unclear, and we exclude the amount of contrast medium from statistical analyses.

If left atrium-PV conduction persisted after cryoballoon ablation, an additional touch-up ablation was performed using one of the abovementioned open-irrigated linear ablation catheters with a 3.5-mm tip and the flow rates described below.

Additional ablation was also performed for any AF triggers originating from non-PV foci induced by isoproterenol infusion, and for spontaneous atrial flutter or atrial tachycardia induced by atrial burst stimuli. Empirical ablation, such as left atrial linear ablation, complex fractionated atrial electrogram ablation, or low-voltage area (LVA) ablation, were also performed according to the operator’s judgment.

Followling PV isolation, voltage mapping was performed using a multielectrode mapping catheter or bipolar 3.5-mm tip catheter during sinus rhythm or with pacing from the right atrium. The presence of LVAs was defined as areas with voltage <0.5 mV covering ≥5 cm² across the total surface area of the left atrium.

Radiofrequency energy was applied for 30 s at each site up to a maximum temperature of 42°C and maximum power of 35 W. An irrigation flow rate of 17 mL/min was used with the Thermocool SmartTouch, NAVISTAR Thermocool, and TactiCath SE catheters. With all other catheters, an irrigation flow rate of 8 mL/min was used. We excluded saline perfusion volumes of multielectrode catheters from statistical analyses because there were no data about the atrium dwell time of multielectrode mapping catheters.

Follow-up

DHF was defined as heart failure requiring medical therapy (e.g., diuretics or inotropic agents) during postablation hospitalization within 2 days after the procedure. A 12-lead electrocardiogram (ECG) and blood tests (hemoglobin, B-type natriuretic peptide [BNP], N-terminal pro BNP [NT-proBNP], estimated glomerular filtration rate, albumin, and C-reactive protein) were performed 1 day before the procedure. In accordance with Japanese Circulation Society guidelines, we set cut-off values for BNP and NT-proBNP of 100 and 400 ng/L, respectively. A 12-lead ECG was performed 1 day after the procedure, and the change in heart rate was calculated by subtracting heart rate before ablation from heart rate after ablation. For 2 days after the procedure, patients underwent ECG monitoring, peripheral oxymoglobin saturation monitoring, and nurse observations. In general, chest X-rays and additional ECGs were also obtained when DHF occurred. If the ECG record was not obtainable, the pulse rate was measured and substituted for heart rate.

Early recurrence of AF was defined as atrial tachyarrhythmias detected by 12-lead ECG or atrial tachyarrhythmias lasting >30 s detected by ECG monitoring after the procedure. If early recurrence of AF occurred, antiarrhythmic drugs were generally administered. Electrical cardioversion was performed according to the chief doctor’s judgment.

Statistical Analysis

Categorical data are presented as absolute values and percentages, and continuous data are presented as the mean ± SD or as the median with interquartile range (IQR). Tests for significance were conducted using the Chi-squared test for categorical variables and the unpaired t-test or Mann-Whitney U test for continuous variables. Patient characteristics (Table 1) and procedural characteristics were compared between patients with and without DHF. Univariate and multivariate Cox proportional hazards regression analyses were used to determine clinical factors associated with DHF. Variables with P < 0.05 in the univariate models were included in the multivariate analysis.

All analyses were performed using commercially available software (SPSS version 25; SPSS, Chicago, IL, USA).

Results

Patients and Procedural Characteristics

PV isolation was successfully completed in all 1,004 patients, using Carto 3 in 822 (82%), Ensite NavX in 159 (16%), and Rhythmia in 23 (2%). Procedural characteristics between
Heart Rate and Decompensated Heart Failure

DHF occurred in 22 of 1,004 (2%) patients. Of the 22 patients with DHF, 14 (64%) had heart failure with a preserved ejection fraction and 7 (32%) had heart failure with a reduced ejection fraction; no echocardiography data before catheter ablation for 1 patient. Two (9%) patients developed early recurrence of AF before DHF. Pilsicainide was used for the management of early recurrence of AF. A representative case of DHF is shown in Figure 2.

The time course and heart rate from the procedure to DHF are shown in Figure 3, and the details of patients with DHF are presented in Table 3.

Patients with DHF had a higher prevalence of persistent AF, past history of symptomatic heart failure, diuretic use, elevated BNP or NT-proBNP, and LVAs than those without DHF (median 67 (IQR 55–83) vs. 66 (IQR 52–87) μg; P=0.92).

| Table 1. Characteristics of Patients With and Without DHF |
|-----------------|-----------------|-----------------|--------|
|                  | All (n=1,004)   | With (n=22)     | Without (n=982) | P value |
| Age (years)      | 68±10           | 70±8            | 68±10           | 0.32    |
| Female sex       | 346 (34)        | 6 (27)          | 340 (35)        | 0.47    |
| Persistent AF    | 513 (51)        | 20 (91)         | 493 (60)        | 0.0002  |
| BMI (kg/m²)      | 24±4            | 25±6            | 24±4            | 0.24    |
| CHA2DS2-VASc score | 2.5±1.4     | 2.6±1.3         | 2.5±1.4         | 0.59    |
| NYHA class       | 1 [1–1]         | 2 [1–2]         | 1 [1–1]         | <0.0001 |
| Past history of symptomatic HF | 171 (17)    | 11 (50)         | 160 (16)        | <0.0001 |
| HFrEF            | 64 (38)         | 6 (60)          | 58 (37)         | 0.14    |
| HFrEF            | 105 (62)        | 4 (40)          | 101 (64)        | 0.14    |
| Hypertension     | 568 (57)        | 9 (41)          | 559 (57)        | 0.13    |
| Diabetes         | 167 (17)        | 3 (14)          | 164 (17)        | 0.70    |
| Pacemaker        | 24 (2)          | 0 (0)           | 24 (2)          | 0.46    |
| Hemodialysis     | 29 (3)          | 0 (0)           | 29 (3)          | 0.41    |
| RAS blocker      | 358 (36)        | 9 (41)          | 349 (36)        | 0.60    |
| Diuretics        | 183 (18)        | 9 (41)          | 174 (18)        | 0.005   |
| Aldosterone receptor antagonist | 69 (7)        | 3 (14)          | 66 (7)          | 0.21    |
| β-blocker        | 352 (35)        | 10 (46)         | 342 (35)        | 0.30    |

Unless indicated otherwise, data are given as the mean ± SD, median [interquartile range], or n (%). AF, atrial fibrillation; BMI, body mass index; BNP, B-type natriuretic peptide; CRP, C-reactive protein; DHF, decompensated heart failure; eGFR, estimated glomerular filtration rate; HF, heart failure; NT-proBNP, N-terminal pro B-type natriuretic peptide; HFrEF, heart failure with preserved ejection fraction; HFrEF, heart failure with reduced ejection fraction; LV, left ventricle; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; RAS, renin-angiotensin system.

Change in Heart Rate

The mean heart rate before and after the procedure was 78±21 and 80±14 beats/min, respectively, giving a mean change in heart rate of ±22 beats/min. Cardiac rhythm before the procedure was sinus rhythm in 464 (46%) patients and AF in 540 (54%) patients. As for cardiac rhythm before the procedure, heart rate decreased significantly after the procedure in patients with AF. In contrast, heart rate significantly increased after the procedure in patients with sinus rhythm (Figure 1).

Decompensated Heart Failure

DHF occurred in 22 of 1,004 (2%) patients. Of the 22 patients with DHF, 14 (64%) had heart failure with a preserved ejection fraction and 7 (32%) had heart failure with a reduced ejection fraction; no echocardiography data before were available catheter ablation for 1 patient. Two (9%) patients developed early recurrence of AF before DHF. Pilsicainide was used for the management of early recurrence of AF. A representative case of DHF is shown in Figure 2.

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Of patients with pacemaker implantation, 5 (20%) were implanted with implantable cardioverter deﬁbrillators and 4 (17%) were implanted with cardiac resynchronization therapy deﬁbrillators. No patients were implanted with cardiac resynchronization therapy pacemakers. Propofol was used in 37 (4%) patients, and dexmedetomidine was used in 967 (96%) patients. The total amount of dexmedetomidine was similar between patients with and without DHF (median 67 (IQR 55–83) vs. 66 (IQR 52–87) μg; P=0.92).

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needed. Two (9%) patients needed temporary cardiac pac- ing for bradycardia. All patients were discharged from hospital. The median New York Heart Association class at discharge was 1 (IQR 1–1).

**Change in Heart Rate and DHF**

A decrease in heart rate after the procedure was an independent predictor of DHF; therefore, subgroup analysis according to the change in heart rate was also performed.

![Figure 1](image-url)

**Figure 1.** Heart rate before and after catheter ablation for atrial fibrillation (AF). Patients were grouped according to cardiac rhythm before the procedure into those with AF or those in sinus rhythm (SR). After the procedure, heart rate decreased significantly in patients with AF, but increased significantly in those with SR. Data are the mean ± SD.

| Table 2. Procedural Characteristics in Patients With or Without DHF |
|---------------------------------------------------------------|
| All (n=1,004) | DHF | Without (n=982) | P value |
| Procedural time (min) | 99±32 | 101±32 | 99±32 | 0.79 |
| Fluoroscopy time (min) | 21±10 | 21±7 | 21±10 | 0.93 |
| Balloon ablation | 320 (32) | 4 (18) | 316 (32) | 0.16 |
| Presumed irrigation volume during the procedure (L) | 0.225±0.242 | 0.248±0.196 | 0.225±0.243 | 0.65 |
| Presumed infusion volume (L) | 0.411±0.255 | 0.409±0.228 | 0.371±0.291 | 0.54 |
| Periprocedural period (L) | 1.819±0.364 | 1.859±0.228 | 1.821±0.291 | 0.54 |
| Low-voltage areas | 206 (21) | 10 (46) | 196 (20) | 0.003 |
| Additional ablation | | | |
| Cavotricuspid isthmus linear ablation | 149 (15) | 1 (5) | 148 (15) | 0.17 |
| Non-pulmonary vein trigger ablation | 31 (3) | 0 (0) | 31 (3) | 0.40 |
| Left atrial linear ablation | 80 (7) | 4 (18) | 76 (8) | 0.07 |
| Low-voltage area ablation | 86 (9) | 5 (23) | 81 (8) | 0.02 |
| CFAE ablation | 24 (2) | 1 (5) | 23 (2) | 0.50 |

Unless indicated otherwise, data are given as the mean ± SD or n (%). CFAE, complex fractionated atrial electrogram; DHF, decompensated heart failure.
Heart Rate and Decompensated Heart Failure

Persistent AF was significantly associated with a decrease in heart rate (Figure 4A). The change in heart rate did not differ significantly between patients with AF duration <1 and ≥1 year (2±22 vs. −1±19 beats/min, respectively; P=0.17).

In patients with paroxysmal AF, past history of symptomatic heart failure and low LVEF were significantly associated with a decrease in heart rate (Figure 4B). Similarly, in patients with persistent AF, a past history of symptomatic heart failure and low LVEF were significantly associated with a decrease in heart rate. Although not significant, there was a tendency for heart rate to decrease in patients using β-blockers compared with those not using β-blockers (Figure 4C). Conversely, in patients with paroxysmal AF, there was no difference in the decrease in heart rate.
there was also no difference in the decrease in heart rate between patients with and without β-blockers. There was also no difference in the decrease in heart rate between patients with and without LVAs (Figure 4B, C).

Discussion

In the present retrospective study of 1,004 patients undergoing initial AF ablation, we found that DHF requiring medical therapy during postablation hospitalization within 2 days after the ablation occurred in 22 (2%) patients. Heart rate decrease after the procedure was an independent predictor of DHF. To the best of our knowledge, this is the first clinical study to investigate the association between heart rate and postprocedural DHF in patients undergoing AF ablation.

Change in Heart Rate and DHF

In this study, DHF occurred in 2% of patients within 2 days after AF ablation. A previous study reported a 3% incidence in pulmonary edema after electrical cardioversion; other studies have shown that 20–26% of patients undergoing AF ablation experience symptoms of heart failure within 30 days after the procedure.4,5 In the present study, a heart rate decrease after AF ablation was an independent predictor of DHF. Both a high heart rate before the procedure and a decrease in heart rate after the procedure were associated with DHF.

Although preprocedural tachycardia is a recognized independent prognostic risk factor for heart failure, an increase in heart rate with increasing severity of heart failure is considered to be a compensatory response to the reduced cardiac reserve via activation of sympathetic activity.14,15 In addition, some AF patients develop tachycardia-induced cardiomyopathy.16 In patients with tachycardia-induced cardiomyopathy, it takes 4–6 weeks after sinus conversion for LVEF to improve.17 In these patients, a decrease in heart rate after the procedure may induce DHF.

A decrease in heart rate can occur after AF ablation. In general, heart rate is higher in patients with AF than in those with sinus rhythm, and sinus node dysfunction frequently occurs in patients with AF.18 Sedation during the procedure also results in a decrease in heart rate.26 These factors lead to DHF immediately after ablation.

In addition, an adaptation failure of cardiac function after AF termination seems to be another cause of DHF. In general, cardiac output decreased in patients with AF due to loss of atrial contraction, irregular beats, and tachycardia.14,15 After the ablation procedure, there is an increase in heart rate and/or cardiac contraction to compensate for a sudden decrease in heart rate.29 Although atrial contraction recovers after recovery of sinus rhythm, some patients cannot compensate for changes in cardiac output, and DHF may occur.

Clinical Implications

Heart rate is an easily observed variable, and risk assessment for DHF after catheter ablation may be useful for safe periprocedural management. If heart rate decreases after catheter ablation, close observation of symptoms is needed in the early phase after the procedure.

The use of β-blockers was significantly associated with a decrease in heart rate in the present study; therefore, a high dose of a β-blocker may cause bradycardia after catheter ablation. Although β-blockers were continued during periprocedural periods in the present study, cessation of β-blockers during periprocedural periods may reduce bradycardia after catheter ablation.

Study Limitations

Several limitations of our study warrant mention. First, infusion volume during the periprocedural period and ablation procedure may have varied, even though we attempted to standardize volumes as far as possible. Second, we could not fully eliminate confounding factors because this was a retrospective study, and so there were some differences in patient characteristics between those with and without DHF. Third, some patients in this study were implanted with a pacemaker. In these patients, the pacemaker may have prevented bradycardia. Finally, the number of cases of DHF was small, weakening the statistical analysis.

Conclusions

DHF occurred in 2% of patients with AF after catheter ablation. A decrease in heart rate after the procedure was an independent predictor of DHF after catheter ablation.
Table 4. Predictors of DHF

|                     | With (n=22) | Without (n=982) | Univariate analysis | Multivariate analysis |
|---------------------|-------------|-----------------|---------------------|----------------------|
| HR (95% CI)         | P value     | HR (95% CI)     | P value             |
| Age (×10 years)     | 7.0±0.8     | 6.8±1.0         | 1.3 (0.8–1.9)       | 0.32                 |
| Female sex          | 6 (27)      | 340 (35)        | 0.7 (0.3–1.8)       | 0.47                 |
| Persistent AF       | 20 (91)     | 493 (50)        | 9.7 (2.3–41)        | 0.002                |
| NYHA class          | 2 [1–2]     | 1 [1–1]         | 3.9 (2.4–6.2)       | <0.0001              |
| Past history of symptomatic HF | 11 (50) | 160 (11) | 4.9 (2.1–11) | 0.0002 |
| Diuretics           | 9 (41)      | 174 (18)        | 3.1 (1.3–7.3)       | 0.008                |
| ∆ Heart rate (beats/min) | −21±29 | 2±21 | 0.97 (0.95–0.98) | <0.0001 |
| ∆ Heart rate (×10 beats/min) | −2.1±2.9 | 0.2±2.1 | 0.7 (0.6–0.8) | <0.0001 |
| BNP ≥100ng/L or NT-proBNP ≥400ng/L | 19 (95) | 547 (57) | 14 (1.9–104) | 0.01 |
| Albumin (g/L)       | 37±5        | 41±4            | 0.2 (0.1–0.4)       | <0.0001              |
| CRP (mg/L)          | 2.5 [1.0–6.5] | 1.0 [1.0–2.0] | 1.4 (1.01–2.0)      | 0.04                 |
| LVEF (×10%)         | 5.1±1.6     | 6.2±1.2         | 0.6 (0.5–0.8)       | 0.0001               |
| LV mass index (×10 g/m²) | 12.8±2.9 | 10.8±3.0 | 1.2 (1.1–1.3) | 0.002 |
| Left atrial diameter (×10mm) | 4.5±0.8 | 4.0±0.7 | 2.6 (1.5–4.5) | 0.001 |
| Low-voltage areas   | 10 (46)     | 196 (20)        | 3.2 (1.4–7.5)       | 0.006                |

Unless indicated otherwise, data are given as the mean ± SD, median [interquartile range], or n (%). CI, confidence interval; HR, hazard ratio; NT-proBNP, N-terminal pro B-type natriuretic peptide. Other abbreviations as in Table 1.

Figure 4. Subgroup analyses of changes in heart rate after catheter ablation for atrial fibrillation (AF). (A) Persistent AF was significantly associated with a decrease in heart rate. (B,C) In patients with paroxysmal (B) and persistent (C) AF, a past history of symptomatic heart failure and low left ventricular ejection fraction (LVEF) were significantly associated with a decrease in heart rate. Data are the mean ± SD.
