ISSN: 2378-2951

Sato et al. Int J Clin Cardiol 2019, 6:155

DOI: 10.23937/2378-2951/1410155

Volume 6 | Issue 4

Open Access

International Journal of
Clinical Cardiology

ORIGINAL ARTICLE

Predictors of Heart Failure Caused by Volume Overload Using an Irrigation Catheter during Catheter Ablation for Atrial Fibrillation

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Abstract

Background: Predictors of heart failure caused by volume overload are unclear. This study to investigate the predictors of heart failure caused by volume overload using an irrigation catheter during atrial fibrillation (AF) ablation.

Methods: This study included 431 consecutive patients with AF who underwent ablation in their first session from April 2009 to December 2015. According to right ventricular systolic pressure (RVSP) after AF ablation, patients were divided into high (≥ 40 mmHg, n = 62) or normal RVSP (< 40 mmHg, n = 312) groups.

Results: There were significant differences in the rates of age ≥ 65-years-old (53.2% vs. 32.1%), history of congestive heart failure (16.1% vs. 8.0%), hypertension (67.7% vs. 50%), and diabetes mellitus (25.8% vs. 6.4%), as well as serum creatinine concentrations (0.92 vs. 0.83 mg/dl), B-type natriuretic peptide levels (165.9 vs. 109.0 pg/ml), left atrial dimension (44.4 vs. 41.0 mm), mitral inflow E wave velocity before ablation (E wave, 76.6 vs. 70.2 cm/sec), and the total amount of injection (3591 vs. 3282 ml) between the high and normal RVSP groups. There were no significant differences in sex, body mass index, left ventricular ejection fraction, and radiofrequency duration. Age ≥ 65-years-old (p = 0.004), history of diabetes mellitus (p < 0.001), left atrial dimension (p = 0.021), and E wave (p = 0.049) showed significant differences in multiple analysis between the high and normal RVSP groups.

Conclusions: Close observation is mandatory with an older age, greater left atrial dimension and mitral E wave, and/or a history of diabetes mellitus to avoid heart failure after AF ablation using irrigation catheters.

Keywords

Ablation, Atrial fibrillation, Irrigation catheter, Volume overload

Introduction

Catheter ablation is an effective approach for managing patients with atrial fibrillation (AF) [1-7]. Currently, irrigation catheters are widely used in AF ablation. This causes volume overload during the procedure and occasionally causes heart failure after the procedure. Volume overload during catheter ablation caused heart failure not only in the patient with reduced ejection fraction but also who with preserved left ventricular ejection fraction. Heart failure with preserved left ventricular ejection fraction is a widely accepted disease [8-10], but there have been few reports of the predictors of heart failure induced by volume overload in clinical practice. Therefore, we investigated the predictors of heart failure caused by volume overload during catheter ablation for AF using an irrigation catheter.

Methods

Study population and protocol

This study comprised 431 consecutive patients (112 females, 319 males, mean age of 60 ± 10 years). We

Citation: Sato T, Yoshimoto I, Oketani N, Okui H, Iriki Y, et al. (2019) Predictors of Heart Failure Caused by Volume Overload Using an Irrigation Catheter during Catheter Ablation for Atrial Fibrillation. Int J Clin Cardiol 6:155. doi.org/10.23937/2378-2951/1410155

Accepted: August 12, 2019; **Published:** August 14, 2019

included 248 (58%) patients with paroxysmal AF and 183 (42%) patients with persistent/long-standing persistent AF with symptomatic drug refractory AF. These patients successfully underwent complex fractionated atrial electrogram (CFAE)-guided ablation combined with (n = 137) or without (n = 288) pulmonary vein isolation from April 2009 to December 2015. In this study, according to right ventricular systolic pressure (RVSP) estimated using echocardiography after AF ablation, patients were divided into high (= 40 mmHg, n = 62) or normal RVSP (< 40 mmHg, n = 312) groups. RVSP is one of the most valuable surrogate markers for heart failure and the normal range was below 40 mmHg. We excluded 57 patients whose echocardiographic data before ablation or the day after ablation were not available (n = 39), or RVSP calculated by echocardiography before ablation was ≥ 40 mmHg before ablation (n = 18).

All antiarrhythmic drugs were discontinued at least five half-lives before ablation, with the exception of amiodarone, which was discontinued at least 3 months before ablation. Warfarin, rivaroxaban, or edoxaban was not discontinued, and dabigatran or apixaban was discontinued only on the morning of the procedure. All of the patients provided written informed consent for the procedure. This study protocol was approved by our institutional ethics committee. AF was defined in accordance with the 2007 Heart Rhythm Society Expert Consensus Statement [11]. Paroxysmal AF was defined as recurrent AF (≥ 2 episodes) that terminated spontaneously within 7 days. Persistent AF was defined as AF that was sustained for longer than 7 days or as AF lasting less than 7 days, but necessitating pharmacological or electrical cardioversion. AF lasting longer than 1 year was defined as long-standing persistent AF.

Mapping and ablation of AF

The AF ablation technique, which was described by Nademanee, et al. [7,12,13], was used for this study, as previously reported [14-17]. In brief, a 3.5-mm NaviStar ThermoCool catheter (DF curve; Biosense Webster, Diamond Bar, CA, USA) was used in all cases, and the irrigation flow was 30 ml/min. After the coronary sinus (CS) was cannulated via the femoral vein by a decapolar catheter (Biosense Webster) for recording and induction, patients underwent non-fluoroscopic electroanatomical mapping with CARTO3 (Biosense Webster). Heparin (5000 IU for the initial bolus, 1000-2000 IU for subsequent boluses as required to maintain an activated clotting time > 300s) was administered for anticoagulation.

All electroanatomical maps were created for patients who were in AF, which occurred spontaneously or by induction. Burst pacing using a CS catheter to a lower limit of 1:1 capture or up to 150 ms was used to induce AF occasionally with a 0.01-0.02 µg/kg/min isoproterenol infusion. When AF was terminated during the ablation procedure in patients with paroxysmal AF, AF was re-induced until it was no longer inducible because paroxysmal AF could be terminated spontaneously. Electroanatomical maps were created and displayed as a shortest complex interval map, and the areas of the CFAE were also identified manually, tagged, and associated with the atrial anatomy created by CARTO3. This enabled the operators to associate areas of the CFAE with the left atrium (LA), CS, and occasionally the right atrium, thereby identifying target sites for ablation.

Bipolar recordings were filtered at 30-500 Hz and the CFAE was defined as follows: 1) fractionated electrograms composed of two or more deflections and/or a perturbation of the baseline with continuous deflection of a prolonged activation complex; and 2) atrial electrograms with a short cycle length (≤ 120 ms).

After acquiring the shortest complex interval map associated with the CFAE, we searched the areas of CFAEs by referring to the tagged points because these areas have temporal spatial stability. Radiofrequency applications were delivered with a maximal power of 40 W with irrigation rates of 30 ml/min (3.5-mm NaviStar ThermoCool catheter; Biosense Webster). The power was reduced to 15 W in the posterior LA closed to the esophagus or in the CS. The primary endpoints during RF ablation were either complete elimination of areas of the CFAE or conversion of AF to sinus rhythm occasionally with injection of nifekalant (0.3 mg/kg intravenously over 10 min, maximum of twice). Nifekalant is a Class III antiarrhythmic drug similar to ibutilide, which is not available in Japan. If the atrial arrhythmias were not successfully terminated, internal cardioversion was performed.

Possible predictors

The patients' background, blood analysis before ablation, echocardiographic data before ablation, medications, some data in AF ablation, such as the volume of injection, and the procedure time were analyzed.

Statistical analysis

According to RVSP after AF ablation, patients were divided into high (≥ 40 mmHg, n = 62) or normal RVSP (< 40 mmHg, n = 312) groups. All continuous data are presented as the mean value ± standard deviation. Data were analyzed using the unpaired Student's t-test in equal variance or Welch's t-test in unequal variance. Disease prevalence, sex, and the proportion of patients taking medications were compared between the two groups using Pearson's chi-square test. Fisher's exact test was used to determine statistical significance in the analysis of contingency tables in which sample sizes were small. Odds ratios (ORs) were calculated by multivariate analysis with logistic regression analysis. Differences between the two groups were considered significant at a p value < 0.05. All statistical analyses were performed with JMP® Pro version 11 (SAS Institute, Inc., Cary, NC, USA) for Windows.

Table 1: Patients characteristics.

	High RVSP (n = 62)	Normal RVSP (n = 312)	p value
age (years old)	65.4 ± 8.4	59.3 ± 10.7	< 0.001
gender (female) [n (%)]	14 (22.5)	87 (27.9)	0.39
body weight (kg)	66.4 ± 11.1	65.6 ± 11.1	0.588
body mass index (kg/m²)	24.7 ± 3.8	24 ± 3.2	0.141
paroxysmal/persistent AF [n (%)]	35 (56.5)/27 (43.5)	128 (41.0)/184 (59.0)	0.025
CHADS2 score	1.6 ± 1.1	0.9 ± 1.0	< 0.001
CHA2DS2-VASc score	2.6 ± 1.5	1.6 ± 1.4	< 0.001
congestive heart failure [n (%)]	10 (16.1)	25 (8.0)	0.045
hypertension [n (%)]	42 (67.7)	156 (50.0)	0.011
age ≥ 5-years-old [n (%)]	33 (53.2)	100 (32.1)	0.002
Age ≥ 75-years-old [n (%)]	8 (12.9)	16 (5.1)	0.023
diabetes mellitus [n (%)]	16 (25.8)	20 (6.4)	< 0.001
stroke/TIA [n (%)]	12 (19.3)	31(9.9)	0.034
Preprocedural examination			
mean of both CAVI	8.49 ± 1.37	7.95 ± 1.21	0.002
mean of both baPWV (cm/sec)	1658.2 ± 306.0	1509 ± 299.6	0.001
creatinine (mg/dl)	0.92 ± 0.29	0.83 ± 0.25	0.012
eGFR (ml/min/1.73m²)	61.8 ± 15.9	69.3 ± 16.2	0.001
hemoglobin (g/dl)	14.3 ± 1.6	14.9 ± 8.5	0.226
BNP (pg/ml)	165.9 ± 157.9	109 ± 120.7	0.009
NT-proBNP (pg/ml)	663.8 ± 894.9	378.3 ± 466.5	0.017
CRP (mg/dl)	0.14 ± 0.23	0.10 ± 0.25	0.203
HbA1c (%)	5.8 ± 0.9	5.4 ± 0.5	0.006
Echocardiography before ablation			
LA dimension (mm)	44.4 ± 6.3	41.0 ± 6.5	0.001
LA volume (ml)	77.2 ± 25.7	68.3 ± 27.7	0.022
LAVI (ml/m²)	43.1 ± 14.0	38.4 ± 13.3	0.024
LV ejection fraction (%)	64.1 ± 12	63.8 ± 10.2	0.874
LV end-diastolic diameter (mm)	47.1 ± 4.6	47.5 ± 4.9	0.512
LV end-systolic diameter (mm)	30.2 ± 6.2	30.6 ± 5.6	0.585
LV mass index (g/m²)	106.9 ± 32.6	101.4 ± 30.5	0.289
Mitral inflow E wave (cm/sec)	76.6 ± 22.9	70.2 ± 22.1	0.039
deceleration time (msec)	186.5 ± 54.7	193.3 ± 50.5	0.36
Peak flow velocity of TR (m/sec)	2.3 ± 0.2	2.2 ± 0.2	< 0.001
RVSP (mmHg)	31.8 ± 4.5	30.0 ± 3.6	0.004
IVC during exhalation (mm)	12.4 ± 3.3	12.7 ± 4	0.513
IVC during inspiration (mm)	7.2 ± 3.0	7.5 ± 3.0	0.551
tissue doppler septal e' wave (cm/sec)	7.1 ± 1.9	7.9 ± 2.5	0.006
tissue doppler lateral e' wave (cm/sec)	10.4 ± 3.3	10.8 ± 3.5	0.353
E/e' septal	11.3 ± 4.3	9.6 ± 4.1	0.003
E/e' lateral	8.0 ± 3.7	7.0 ± 3.0	0.058
LA appendage flow velocity calculated by TEE (cm/s)	41.1 ± 21.5	47 ± 20.8	0.046
medication			
ACE/ARB [n (%)]	33 (53.2)	113 (36.2)	0.012
beta blocker [n (%)]	29 (46.8)	126 (40.4)	0.351
class 1 antiarrhythmic drugs [n (%)]	15 (24.2)	118 (37.8)	0.043
verapamil, diltiazem [n (%)]	17 (27.4)	68 (21.8)	0.325

diuretics [n (%)]	16 (25.8)	44 (14.1)	0.022
catheter ablation			
dose of contrast (ml)	8.4 ± 16.4	6.9 ± 15.8	0.491
procedure duration (minutes)	226.3 ± 52.3	216.5 ± 55.1	0.202
radiofrequency duration (minutes)	93.7 ± 28.4	88.9 ± 31.3	0.267
total injection (ml)	3591.2 ± 937.8	3282.1 ± 995.2	0.028
in/out balance (ml)	1826 ± 1168.9	1573.7 ± 888.1	0.112
maximum heart rate in AF (bpm)	94.8 ± 18.4	105 ± 24.9	< 0.001
maximum systolic blood pressure (mmHg)	144.8 ± 23.0	144.4 ± 23.1	0.91
with/without PVI	20/42	100/212	0.975

AF: Atrial fibrillation; TIA: Transient ischemic attack; CAVI: Cardio-ankle vascular index; baPWV: Brachial-ankle pulse wave velocity; eGFR: Estimated glomerular filtration rate; BNP: B-type natriuretic peptide; NT-proBNP: N-terminal pro-B-type natriuretic peptide; CRP: C-reactive protein; HbA1c: Hemoglobin A1c; LA: Left atrial; LAVI: Left atrial volume index; LV: Left ventricular; TR: Tricuspid valve regurgitation; RVSP: Right ventricular systolic pressure; IVC: Inferior vena cava; TEE: Transesophageal echocardiography; ACEI: Angiotensin-converting enzyme inhibitor; ARB: Angiotensin receptor blocker; PVI: Pulmonary vein isolation.

Results

The patients characteristics and procedural data are shown in Table 1. We retrospectively analyzed the data the day after ablation. According to RVSP the day after ablation, we divided the patients into two groups as follows: high RVSP group (RVSP ≥ 40 mmHg the day after ablation, n = 62) and normal RVSP group (RVSP < 40 mmHg the day after ablation, n = 312).

Univariate analysis

Comparison of characteristics of patients between the normal and high RVSP groups is shown in Table 1. Age was older in the high RVSP group than in the normal RVSP group (p < 0.001). The prevalence of paroxysmal AF was greater in the high RVSP group than in the normal RVSP group (p = 0.025). CHADS2 score (p < 0.001) and CHA2DS2-VASc score (p < 0.001) were higher in the high RVSP group than in the normal RVSP group. In the components of CHADS2 score, age ≥ 65-years-old (p = 0.002), history of congestive heart failure (p = 0.045), hypertension (p = 0.011), diabetes mellitus (< 0.001), stroke/transient ischemic attack (p = 0.034) were higher in the high RVSP group than in the normal RVSP group. Mean cardio-ankle vascular index (p = 0.002) and mean brachial-ankle pulse wave velocity (p = 0.001) were higher in the high RVSP group than in the normal RVSP group. In the blood sample examination before procedure, serum creatinine concentrations (p = 0.012), estimated glomerular filtration rate (p = 0.001), B-type natriuretic peptide levels (p = 0.009), N-terminal pro-B-type natriuretic peptide levels (p = 0.017), and hemoglobin A1c levels (p = 0.006) were higher in the high RVSP group than in the normal RVSP group. In the echocardiographic data before procedure, LA dimension (p = 0.001), LA volume (p = 0.022), LA volume index (p = 0.024), mitral inflow E wave velocity (p = 0.039), peak flow velocity of tricuspid valve regurgitation (p < 0.001), RVSP (p = 0.004), tissue Doppler septal e' wave velocity (p = 0.006), E/e' septal ratio (p = 0.003) were higher in the high RVSP group than in the normal RVSP group. LA appendage flow velocity calculated by transesophageal echocardiography was higher in the high RVSP group than in the normal RVSP group (p = 0.046). The prevalence of the patients who prescribed angiotensin-converting enzyme inhibitors/angiotensin receptor blockers (p = 0.012) and diuretics (p = 0.022) was higher in the high RVSP group than in the normal RVSP group, and who prescribed class 1 antiarrhythmic drugs (p = 0.043) was less in the high RVSP group than in the normal RVSP group. In the data during procedure, total amount of injection during the procedure was greater in the high RVSP group than in the normal RVSP group (p = 0.028), and maximum heart rate of AF during the procedure less in the high RVSP group than in the normal RVSP group (p < 0.001). Although, there was no significant difference in sex, body mass index, or left ventricular ejection fraction between the two groups.

Multivariate analysis for high RVSP

There were many predictors in multivariate analysis in this study. Then we selected predictors using in multivariate analysis considering the confounding factors as follows. In multivariate analysis, age > 65-years-old (OR 2.62; 95% confidence interval 1.37-5.09; p= 0.004), history of diabetes mellitus (OR 6.7; 95% confidence interval 2.83-16.00; p < 0.001), LA dimension (OR 1.06; 95% confidence interval 1.01-1.13; p = 0.021), and mitral inflow E wave (OR 1.02; 95% confidence interval 1.00-1.03; p = 0.046) were predictors of high RVSP the day after ablation (Table 2).

Discussion

We investigated patients who underwent AF ablation using an irrigation catheter. Until irrigation catheter was available, 8 mm tip catheter had been standard for AF ablation. But irrigation catheter replaced rapidly because of the reduction of the complication of thromboembolic events. But the volume overload in AF ablation with irrigation catheter was not neglectable. More than

Table 2: Multivariate analysis of predictors of high right ventricular systolic pressure.

	odds ratio	CI (95%)	P value
Age ≥ 65-years-old	2.62	1.37-5.09	0.004
mean of both CAVI	1.15	0.89-1.50	0.295
paroxysmal/persistent AF	1.22	0.58-2.56	0.591
creatinine	1.93	0.69-5.52	0.192
total injection during procedure	1	0.99-1.00	0.207
LA dimension before ablation	1.06	1.01-1.13	0.021
mitral inflow E wave (cm/sec)	1.02	1.00-1.03	0.049
diabetes mellitus	6.7	2.83-16.00	< 0.001
congestive heart failure [n (%)]	1.71	0.63-4.26	0.263

CAVI: Cardio ankle vascular index; AF: Atrial fibrillation; LA: Left atrial.

3 liters of injection volume were used in the procedure with the NaviStar ThermoCool catheter. There have been few reports of volume overload in clinical practice [18,19].

In general, left ventricular systolic or diastolic dysfunction is the main reason of heart failure. Then the main reasons of heart failure caused by volume overload are suspected to be lower ejection fraction or diastolic dysfunction estimated by echocardiography. Although ejection fraction was not a predictor of high RVSP after catheter ablation in our data. And the parameters of diastolic left ventricular dysfunction, such as mitral inflow E wave velocity was higher in the high RSVP group, but age or the history of diabetes mellitus is stronger predictors of higher RVSP after catheter ablation using multivariate analysis. Then we may need close observation to the patients of high age and/or who have a history of diabetes, when not only in the patients undergo catheter ablation but also other operations with volume overload. Consideration of age and a history of diabetes mellitus might be helpful to avoid heart failure in the perioperative period.

Study Limitations

There are several limitations to this study. First, this study was retrospectively analyzed from a single center. Therefore, a further prospective, large study is required to confirm our results. Second, the high RVSP group included patients with a higher RVSP and a history of congestive heart failure. There could have been some bias, although a history of congestive heart failure was not a predictor of high RVSP in multiple regression analysis.

Conclusions

Close observation is important with an older age, a history of diabetes mellitus, and a greater LA dimension and/or mitral E wave to avoid heart failure after AF ablation using irrigation catheters.

Funding Sources

This work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI (Grant Number 26461077).

Acknowledgment

We thank Ellen Knapp, PhD, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Conflicts of Interest

There are no conflicts of interest for this study.

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