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ORIGINAL RESEARCH

Complications Associated With Catheter Ablation in Patients With Atrial Fibrillation: A Report From the JROAD-DPC Study

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BACKGROUND: Aging is one of the major concerns and determinants of the indications for catheter ablation (CA) for atrial fibrillation. This study aimed to assess the safety of CA in older patients with atrial fibrillation undergoing CA.

METHODS AND RESULTS: The JROAD-DPC (Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination) is a nationwide claims database using data from the Japanese Diagnosis Procedure Combination/Per Diem Payment System. Among 6 632 484 records found between April 2012 and March 2018 from 1058 hospitals, 135 299 patients with atrial fibrillation (aged 65±10 years, 38 952 women) who underwent CA in 456 hospitals were studied and divided into the following age groups: <60, 60 to 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, and ≥85 years. The overall in-hospital complication rate was 3.4% (cardiac tamponade 1.2%), and in-hospital mortality was 0.04%. Older patients had a higher prevalence of women, lower body mass index, and a higher burden of comorbidities such as hypertension, and all of those characteristics were predictors for complications in multivariate analysis. A multivariate adjusted odds ratio revealed that increased age was independently and significantly associated with overall complications (60–64 years, 1.19; 65–69 years, 1.29; 70–74 years, 1.57; 75–79 years, 1.63; 80–84 years, 1.90; and ≥85 years, 2.86; the reference was <60 years).

CONCLUSIONS: The nationwide JROAD-DPC database demonstrated that the frequency of complications following CA in patients with atrial fibrillation increased according to age.

Key Words: atrial fibrillation ■ catheter ablation ■ complications ■ older ■ Japanese Registry of All Cardiac and Vascular Diseases

The global population is progressively aging, and the number of people aged 65 years and older in Japan has exceeded 25%, which is larger than in any other country in the world.[1] The number of patients with atrial fibrillation (AF) increases as the older population grows.[2] AF is associated with increased mortality and morbidity, with stroke and thromboembolic events being major complications.[3] Furthermore, symptoms such as palpitations result in a worsening quality of life. Therapy with antiarrhythmic drugs is not effective for survival and has toxicities.[4]

Catheter ablation (CA) for AF is widely accepted and has become an effective alternative to drug therapy.[5,6] It has been shown that CA for AF improves the quality of life and reduces the risk of a stroke, cardiovascular event, and mortality.[7–10] Indications for CA are based not only on the tachyarrhythmia-related symptoms and the risk of serious consequences of untreated AF

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CLINICAL PERSPECTIVE

What Is New?

- In a nationwide claims database, early overall complications among patients undergoing catheter ablation for atrial fibrillation between 2012 and 2018 in Japan was 3.4%, and in-hospital mortality was 0.04%.
- The frequency of complications following catheter ablation in patients with atrial fibrillation increased according to age.
- Furthermore, older patients had a higher prevalence of women, lower body mass index, and a higher burden of comorbidities.

What Are the Clinical Implications?

- It is important to determine the indication and strategies of catheter ablation for atrial fibrillation according to the patients' characteristics, including age, sex, and comorbidities, to reduce the impact of outcomes.

Nonstandard Abbreviations and Acronyms

AFL	atrial flutter
AT	atrial tachycardia
AVB	atrioventricular block
CA	catheter ablation
DPC	Diagnosis Procedure Combination
JROAD-DPC	Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination

(eg, heart failure), but they also take into account the risks of the ablation procedure. Recent advance in the ablation technique, better understanding of the electrophysiology and anatomy of the heart, and technological advances have influenced both the safety and success rates of this procedure. There are, however, few safety data on CA for AF in accordance with the detailed age groups and comorbidities.

The JROAD-DPC (Japanese Registry of All Cardiac and Vascular Diseases- Diagnosis Procedure Combination) is a nationwide claims database using data from the Japanese Diagnosis Procedure Combination/Per Diem Payment System.[11] Recently, we analyzed the JROAD-DPC data and reported the current status of cardiovascular medicine in the aging society of Japan.[12] In this study, by using data between April 2012 and March 2018 from the nationwide JROAD-DPC database, we investigated the safety (in-hospital complications and in-hospital mortality) of CA in patients with AF, focusing in particular on the influence of age.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Data Source

This cross-sectional study used the JROAD-DPC database, which has been described in detail previously.[11,12] The JROAD-DPC database includes the following information for each patient: patient age and sex, main diagnoses and comorbidities, drugs and devices, diagnostic and therapeutic procedures, length of stay, unique hospital identifiers, and discharge status.[13] The Diagnosis Procedure Combination (DPC) database contains 6 categories of diagnoses based on the *International Classification of Diseases*, *Tenth Revision* (*ICD-10*) codes, each with a limited number of recordable diseases. One diagnosis each is coded for "main diagnosis," "admission-precipitating diagnosis," "most resource-consuming diagnosis," and "second most resource-consuming diagnosis." A maximum of 4 to10 diagnoses each can be coded for "comorbidities present at time of admission" and "conditions arising after admission." The following data can also be extracted from the DPC database: patient age and sex, height, weight, and body mass index. The CHA_2DS_2-VASc score was calculated for every patient based on a point system in which 2 points are assigned for a history of stroke or transient ischemic attack or age ≥75 years. One point was assigned for age between 65 and 74 years; history of hypertension, diabetes mellitus, heart failure, and vascular disease (prior myocardial infarction or peripheral artery disease); and female sex.

This study received approval from the institutional review board of the National Cerebral and Cardiovascular Center, Japan (R19027, April 25, 2019 and M26-148-9, April 6, 2015) and the Japanese Circulation Society (approval number 2017-14-01). No informed consent was required from participants in this study.

Study Population

The JROAD-DPC database contains 6 632 484 health records from 1058 Japanese Circulation Society–certified hospitals, which were collected between April 2012 and March 2018. Figure 1 shows a flowchart of this study.

Step 1

We extracted patients who were hospitalized for AF identified with a main diagnosis, admission-precipitating diagnosis, most resource-consuming diagnosis, and/or second most resource-consuming diagnosis of I48.

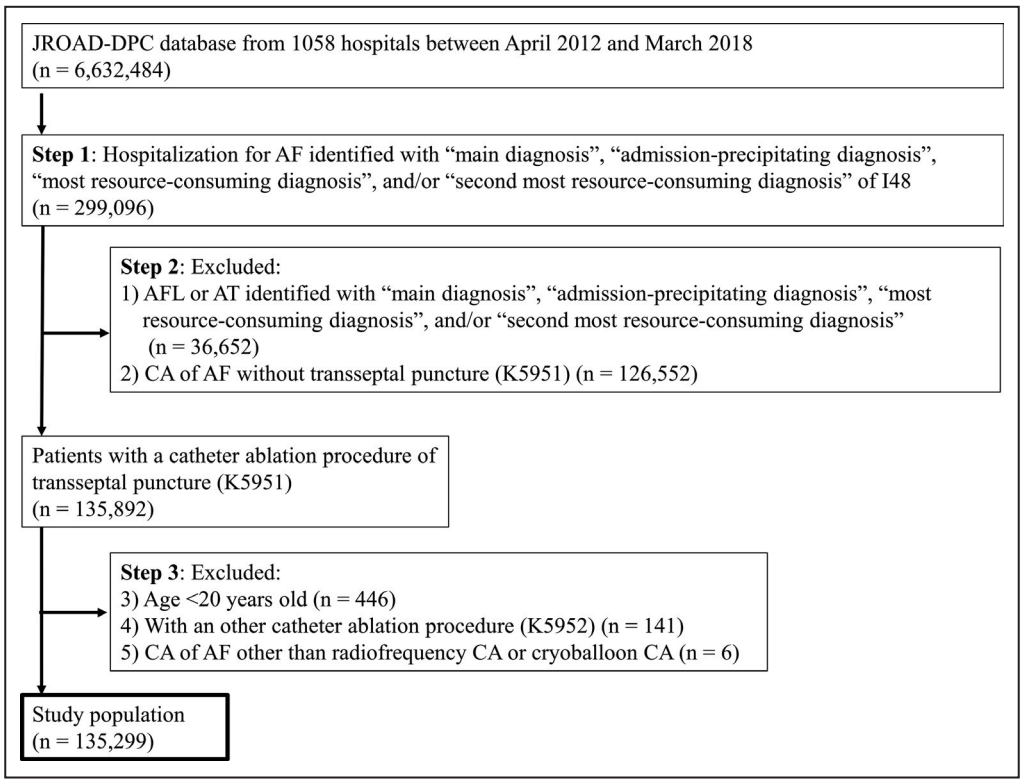

Figure 1. Flowchart of this study.
AF indicates atrial fibrillation; AFL, atrial flutter; AT, atrial tachycardia; CA, catheter ablation; and JROAD-DPC, Japanese Registry of All Cardiac and Vascular Disease-Diagnosis Procedure Combination.

Step 2

We excluded patients with atrial flutter or atrial tachycardia identified with a main diagnosis, admission-precipitating diagnosis, most resource-consuming diagnosis, and/or second most resource-consuming diagnosis, and patients who underwent CA for AF without transseptal puncture.

Step 3

Furthermore, we excluded patients aged <20 years, patients who underwent CA with another CA procedure, and patients who underwent CA for AF other than radiofrequency CA or cryoballoon CA.

Outcome Measurement: Definition of Complications

We identified the common in-hospital complications attributable to CA for AF by using the *ICD-10* diagnosis and DPC procedures codes. In-hospital complications were extracted from a maximum of 4 to 10 diagnoses coded for "conditions arising after admission." Complications were defined on the following *ICD-10* diagnosis and DPC procedure codes (Table S1): cardiac complications (cardiac tamponade: I31.9, I97.1, J98.5, and/or pericardial drainage as J048 or J0021; myocardial infarctions: I21$, I22$, or I23$; vasospastic angina: I20.1; complete atrioventricular block: I44.2; and sick sinus syndrome: I45.5 or I49.5), pulmonary complications (pneumothoraxes: J930, J931, J938, or J939; hemothorax: J942; and pneumonia: J15.9, J18.9, or J69.0), neurological complications (phrenic nerve palsy: G58.8; stroke and transient ischemic attack [TIA]: G45$ or I63$), vascular access complications (hematoma: S701, S801, T140, or T810 and pseudoaneurysms: I72.4), other complications (thromboembolism: H342, I24, I269, I740, I741, I744, I748, I749, K550, K868, N280, T790; blood transfusion: K920, K9201–K9205; and cardiothoracic surgery: K539), and in-hospital death. Enrolled patients were divided into the following age groups: <60, 60 to 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, and ≥85 years.

Statistical Analysis

Categorical data are shown as frequencies and percentages. Continuous data are shown using means with the standard deviations when normally distributed, and median (interquartile range) when not normally distributed. The Shapiro-Wilk test was performed for normality test. Uni- and multivariate mixed-effects logistic regression analyses using the institutes as random intercepts were performed to evaluate whether age was independently associated

with the overall complications. Area under the curve with 95% CI and Hosmer-Lemeshow test for a multilevel mixed model were calculated. Additionally, the Cochran-Armitage trend test category was performed. All analyses were performed using the Statistical Analysis System (version 9.4; SAS Institute, Cary, NC) and Stata 16.0 (StataCorp, College Station, TX).

Accuracy Validation of JROAD-DPC Database

We conducted a validation study of patients who were hospitalized at our institute between April 2012 and March 2016. We used 2 databases for this validation study, the DPC database (n=27 889) and AF ablation database (n=903), from our institute (National Cerebral and Cardiovascular Center) between April 2012 and March 2016. The AF ablation database was created based on clinical hospital records, and 2 cardiologists (Y.Y. and K.M.) confirmed the diagnosis and procedure in all 903 patients who underwent CA for AF.

RESULTS

Study Population

We identified 299 096 hospitalizations for AF identified with *ICD-10* codes (I48) between April 2012 and March 2018 (Figure 1, Step 1). We excluded patients with atrial flutter or atrial tachycardia identified with a main diagnosis, admission-precipitating diagnosis, most resource-consuming diagnosis, and/or second most resource-consuming diagnosis (n=36 652) and patients who underwent CA for AF without transseptal puncture (n=126 552) (Figure 1, Step 2). Furthermore, we excluded patients aged <20 years (n=446), patients who underwent CA with another CA procedure (n=141), and patients who underwent CA for AF other than radiofrequency CA or cryoballoon CA (n=6) (Figure 1, Step 3). As a result, 135 299 patients were included in the present study.

The patients' characteristics are shown in Table 1. The mean age was 64.8 years, and 28.8% of patients were women. A total of 46.7% of patients had hypertension, 15.1% diabetes mellitus, 32.6% heart failure, 14.5% ischemic heart disease, and 1.4% stroke or TIA. The mean CHA_2DS_2-VASc score was 2.05±1.30.

The patients were divided into prespecified groups according to the age at admission (<60, 60–64, 65–69, 70–74, 75–79, 80–84, and ≥85 years) (Table S2). The largest population, except for patients aged <60 years, was patients aged 65 to 70 years (n=30 073), and older patients (aged >70 years) comprised 35.9% (n=48 537)

Table 1. Patient Characteristics

Variable	Value
No. of patients	135 299
Age, y, n (%)	64.8±10.4
<60	35 412 (26.2)
60–64	21 277 (15.7)
65–69	30 073 (22.2)
70–74	26 119 (19.3)
75–79	16 459 (12.2)
80–84	5164 (3.8)
≥85	795 (0.6)
Sex, women, n (%)	38 952 (28.8)
Height, cm	163.4±16.9
Body weight, kg	65.6±14.0
Body mass index	24.2±3.7
Comorbidities, n (%)	
Hypertension	63 192 (46.7)
Diabetes mellitus	20 495 (15.1)
Heart failure, n (%)	44 111 (32.6)
NYHA class I	9569 (69.5)
NYHA class II	3533 (25.7)
NYHA class III	490 (3.6)
NYHA class IV	172 (1.2)
Stroke or TIA, n (%)	1912 (1.4)
Ischemic heart disease, n (%)	19 600 (14.5)
CHA_2DS_2-VASc score	2 [1–3]
$CHADS_2$ score	1 [0–2]
Cryoballoon ablation, n (%)	18 572 (13.7)

NYHA indicates New York Heart Association; and TIA, transient ischemic attack.

of the study population. Older patients had a higher prevalence of women (P<0.001), a lower body mass index, (P<0.001), a higher burden of comorbidities (hypertension, diabetes mellitus, heart failure, ischemic heart disease, and stroke or TIA; P<0.001), and a higher CHA_2DS_2-VASc score (P<0.001) as shown in Figures 2 and 3.

In-Hospital Death and Complications

The in-hospital mortality and complications data in the patients overall are shown in Table 2. The in-hospital mortality was 0.04%, and the overall in-hospital complication rate was 3.4% (cardiac tamponade, 1.2%; stroke or TIA, 1.0%; sick sinus syndrome, 0.36%; pneumonia, 0.28%; vascular access complications, 0.24%; thromboembolism except for strokes/TIA, 0.22%; and myocardial infarction, 0.09%).

In-hospital death occurred more frequently corresponding to higher age (P<0.001). Female sex, lower body mass index, and heart failure were also

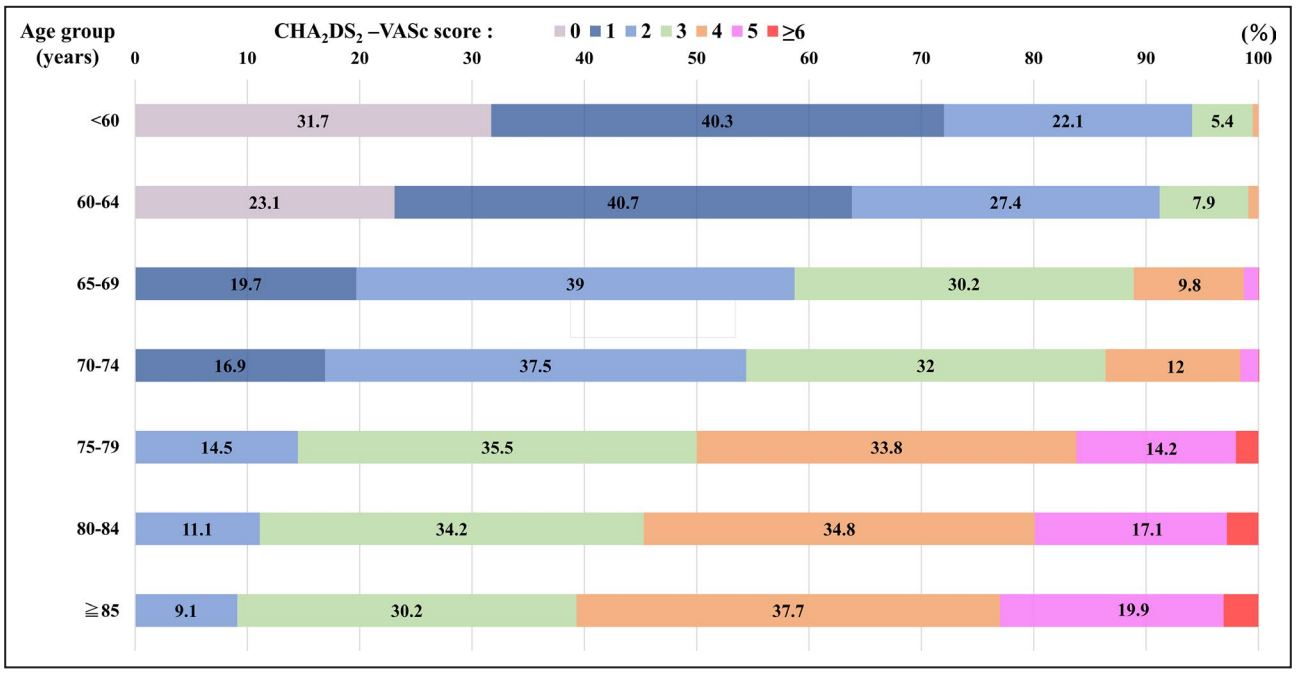

Figure 2. Distribution of the CHA_2DS_2-VASc score in each age group.
The older patients had a significantly higher CHA_2DS_2-VASc score corresponding to higher age (P<0.001).

predictors for mortality in the univariate analysis (Table S3). Similarly, the overall complication rate increased corresponding to age (P<0.001) (Table S4). In particular, the following complications occurred more frequently in the older population: cardiac tamponade, P<0.001; pneumonia, P<0.001; sick sinus syndrome, P<0.001; thromboembolism except for strokes/TIA, P=0.014; and phrenic nerve palsy, P=0.037.

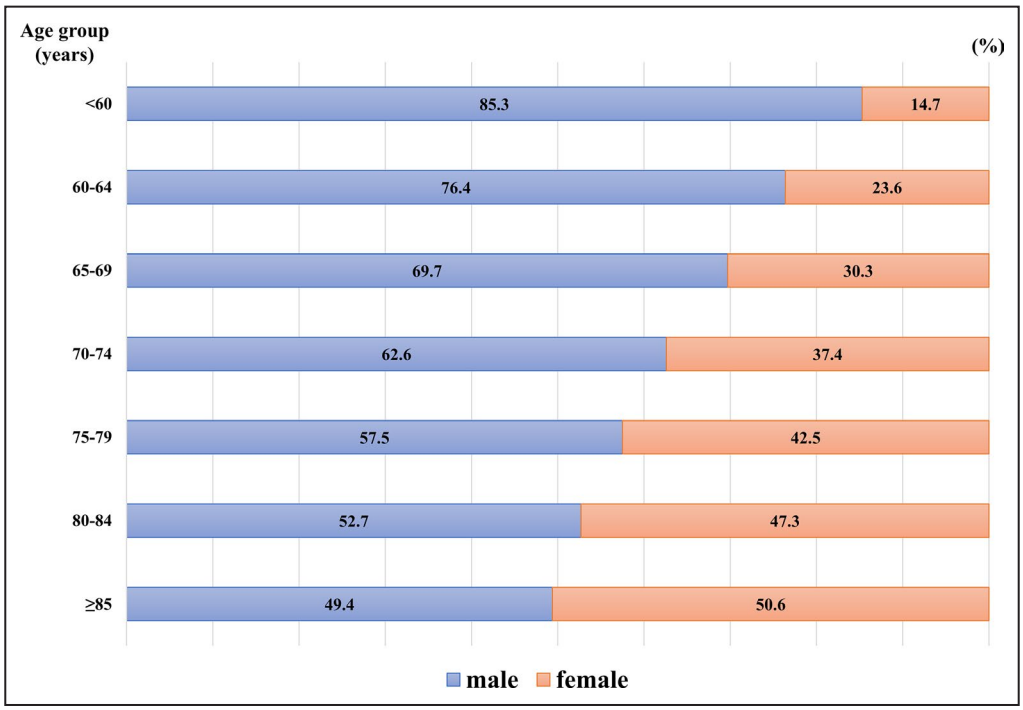

Figure 3. Distribution of sex in each age group.
The older patients had a significantly increased rate of women corresponding to higher age (P<0.001).

Table 2. In-hospital Complications

Variable	Value, N=35 299	95% CI
Overall complications, n (%)	4594 (3.4)	3.30–3.50
Cardiac complications, n (%)		
Cardiac tamponade	1620 (1.2)	1.14–1.26
Myocardial infarction	122 (0.09)	0.07–0.11
Vasospastic angina	100 (0.07)	0.06–0.08
Complete AVB	84 (0.06)	0.05–0.07
Sick sinus syndrome	491 (0.36)	0.33–0.39
Pacemaker implantation	860 (0.6)	0.60–0.68
Pulmonary complications, n (%)		
Pneumothorax	38 (0.03)	0.02–0.04
Hemothorax	19 (0.01)	0.00–0.02
Pneumonia	378 (0.28)	0.25–0.31
Neurological complications, n (%)		
Phrenic nerve palsy	49 (0.04)	0.03–0.05
Stroke or TIA	1325 (1.0)	0.93–1.03
Vascular access complications, n (%)		
Hematoma	216 (0.16)	0.14–0.18
Pseudoaneurysm	107 (0.08)	0.06–0.10
Other complications		
Thromboembolism, n (%)	299 (0.22)	0.20–0.24
Blood transfusion, n (%)	853 (0.6)	0.59–0.67
Cardiothoracic surgery, n (%)	29 (0.02)	0.01–0.03
Length of stay, d	5 [4–7]	
In-hospital death, n (%)	53 (0.04)	0.03–0.05

AVB indicates atrioventricular block; and TIA, transient ischemic attack.

Predictors of In-Hospital Complications

The univariate and multivariate predictors for overall complications are shown in Table 3. Older age, female sex, hypertension, diabetes mellitus, heart failure, and hyperlipidemia were predictors for complications in the multivariate analysis. In the multivariate analysis after an adjustment for sex, hypertension, diabetes mellitus, heart failure, and hyperlipidemia showed that increased age remained independently and significantly associated with overall complications (Figure 4). Figures 4 shows a stepwise increase in the odds ratio of developing in-hospital complications with increasing age when compared with the reference group (aged <60 years), even in the 60 to65 years age group. Figure S1 shows the overall complication rate in each age group according to the CHA_2DS_2-VASc score. In most of the age groups, the overall complication rate increased as the CHA_2DS_2-VASc score increased. Table S5 shows the univariate logistic regression analyses of the overall complications for CHA_2DS_2-VASc score 3, 4, and ≥5. The overall complication rate increased corresponding to the age group who scored 3 (P=0.020 for trend).

Validation of AF and Complication Diagnosis Based on the DPC Database

We examined the accuracy of the DPC database. We extracted patients who underwent CA for AF from 27 889 patients hospitalized at our institute between April 2012 and March 2016 by using the same flowchart as in the present study (Figure S2). As a result, a total of 856 patients were extracted as those who underwent CA for AF. We confirmed that all 856 patients underwent CA for AF by using the institutional AF ablation database. On the other hand, 47 of 903 patients who underwent CA for AF could not be extracted by the DPC database (Figure S2). As a result, the sensitivity of the DPC database to extract patients who underwent CA for AF was 94.7%, and the positive predictive value was 100%.

Next, we examined the accuracy of the DPC database to extract patients who had complications following CA for AF (Figure S3). In 856 patients who were extracted from the DPC database as those who experienced CA for AF (Figure S2), any complications were identified in the DPC database in 22 cases (detailed data are shown in Figure S3). On the other hand, complications following CA for AF were identified with the AF ablation database in 18 cases. As a result, the sensitivity of the DPC database to extract patients who had complications following CA for AF was 100%, and the positive predictive value was 81.8%.

DISCUSSION

The major findings of the present study using the nationwide JROAD-DPC claims database containing >135 000 cases and >450 hospitals between 2012 and 2018 are as follows: (1) the overall complication rate was 3.4% and (2) a multivariate adjusted odds ratio revealed that an increased age was independently and significantly associated with the overall complications (60–65 years, 1.19; 65–70 years, 1.29; 70–75 years, 1.57; 75–80 years, 1.63; 80–85 years, 1.90; and ≥85 years, 2.86; the reference was <60 years).

Validation of the JROAD-DPC Database

There have already been some studies that evaluated the mortality and/or complications following CA for AF by using a nationwide database based on *ICD, Ninth Revision* or *ICD-10* codes, such as the Nationwide Readmissions Database in the United States and the German Diagnosis Related Groups

Table 3. Univariate and Multivariate Logistic Regression Analyses of the Overall Complications

Variable	Univariate		Multivariate		*P* Value for Interaction With Age
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	
Age, y (reference, <60 y)	…	…	1	…	…
60–64	1.24 (1.11–1.37)	<0.001	1.19 (1.07–1.32)	0.001	
65–69	1.37 (1.25–1.50)	<0.001	1.29 (1.17–1.42)	<0.001	
70–74	1.70 (1.55–1.87)	<0.001	1.57 (1.43–1.73)	<0.001	
75–79	1.80 (1.62–1.99)	<0.001	1.63 (1.46–1.82)	<0.001	
80–84	2.14 (1.84–2.48)	<0.001	1.90 (1.63–2.21)	<0.001	
≥85	3.24 (2.41–4.36)	<0.001	2.86 (2.12–3.85)	<0.001	
Sex, women	1.34 (1.26–1.44)	<0.001	1.21 (1.14–1.30)	<0.001	0.237
Hypertension	1.23 (1.15–1.31)	<0.001	1.14 (1.07–1.21)	<0.001	0.002
Diabetes mellitus	1.25 (1.16–1.36)	<0.001	1.21 (1.12–1.32)	<0.001	0.950
Heart failure	1.25 (1.16–1.34)	<0.001	1.22 (1.14–1.32)	<0.001	0.101
Hyperlipidemia	1.22 (1.13–1.30)	<0.001	1.14 (1.06–1.23)	<0.001	0.895
CHA_2DS_2-VASc score	1.23 (1.20–1.26)	<0.001	…	…	…
$CHADS_2$ score	1.21 (1.17–1.25)	<0.001	…	…	…
Radiofrequency CA	1.02 (0.92–1.12)	0.769	…	…	…

P<0.001 for trend in each age group. Area under the curve=0.754 (0.746–0.761).
Hosmer-Lemeshow test for multilevel mixed model *P*=0.18.
CA indicates catheter ablation; and OR, odds ratio.

System.[14] These studies are valuable, but they are limited by the accuracy of encoding of the *ICD* diagnosis and procedure codes, and miscoding and/or overcoding may influence the quality of the study. Hence, we conducted a validation study to examine (1) the accuracy of the DPC database to extract patients who underwent CA for AF and (2) the accuracy of the DPC database to extract patients who had complications following CA for AF. The validation analysis in the present study using the detailed institutional registry data demonstrated that the sensitivity and positive predictive value in extracting both patients who underwent the procedure of CA for AF and those who had complications following CA seemed to be relatively high.

Comparison With Previous Studies

There have been previous studies that investigated the safety of CA for AF as shown in Table 4.[14–21] In Japan, Inoue et al retrospectively studied 3373 patients registered in 3 months (September 2011, March

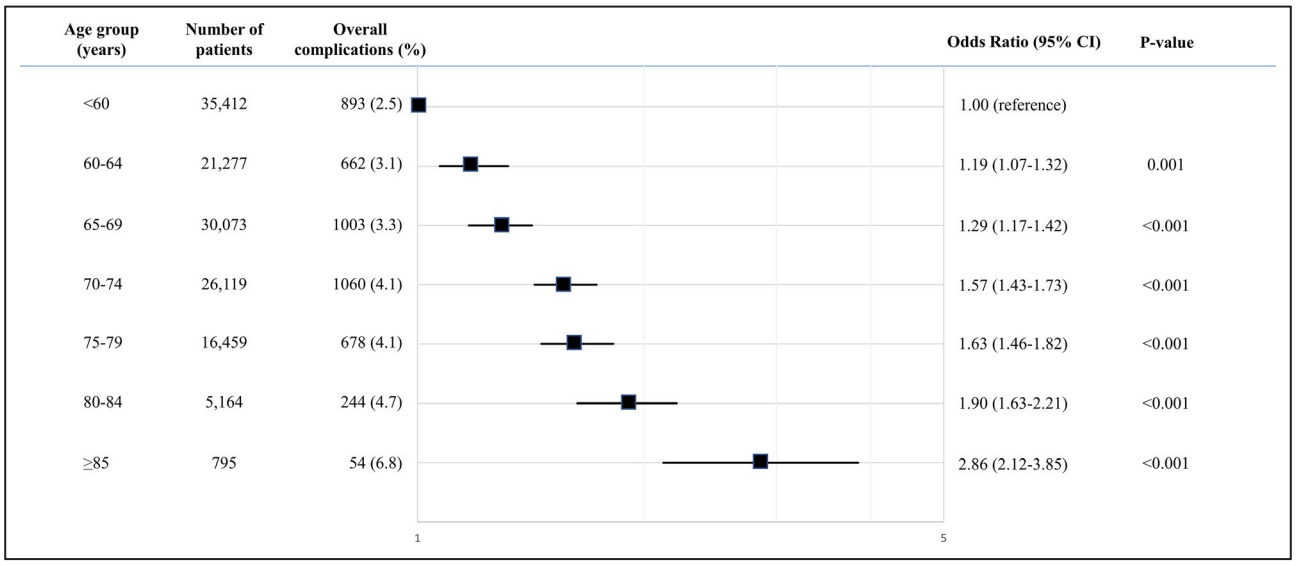

Figure 4. Multivariate analysis odds ratio for the overall complications according to the age group after an adjustment for the sex, hypertension, diabetes mellitus, heart failure, and hyperlipidemia.

Table 4. Characteristics and Complications in Previous Studies

Citation	Reference No.	Country	Year	Sample Size	Age, y	Women, %	Ischemic Heart Disease, %	In-Hospital Death, %	Overall Complications, %	Cardiac Tamponade, %
The present study: JROAD-DPC		Japan	2012–2018	135 305	64.8±10.4	28.8	14.5	0.04	3.4	1.2
Large-scale medical information database										
Deshmukh et al: Claim files from the NIS	16	USA	2000–2010	93 801	NA	40	NA	0.42	6.29	1.52
Piccini et al: Claim files from US Medicare	17	USA	2007–2009	15 423	72.0±5.3	40.6	51.4	0.78	3.2	1.7
Cheng et al: Claim files from HCUP	14	USA	2010–2015	60 203	64.4	38.0	26.9	0.46	6.7	1.9
Investigator-initiated registry/study										
Inoue et al	15	Japan	2011–2012	3373	62.2±10.6	23.9	6.1	0	4.6	1.3
Miyazaki et al	18	Japan	2004–2008	637	NA	22.9	NA	NA	1.7	0.9
Criado et al	19	Spain	2018	3907	NA	NA	NA	NA	3.4	0.8 (pericardial effusion)
Hussein et al	20	USA	2005	831	58.7±9.9	22.5	14.2	0	2.4	0.2
Winkle et al	21	USA	2003–2009	843	61.7±10.3	27.9	12.8	0	1.96	NA

HCUP indicates Healthcare Cost and Utilization Project; JROAD-DPC, Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination; NA, not available; and NIS, Nationwide Inpatient Sample.

2012, and September 2012). The data including the age (62.2± 0.6 years), prevalence of women (23.9%), and $CHADS_2$ score (1.0±1.0) were comparable with those in the present study.[15] The complication rate was 6.2% in the first period of the survey (September 2011), and it decreased to 4.2% in the third period of the survey (September 2012), which was higher than the complication rate of 3.4% in the present study. The difference in complication rate may be related in part to the study period, 2011 to 2012 versus 2012 to 2018.

There have been large-scale studies using claims databases from the United States (Table 4). Deshmukh et al investigated complications following CA for AF performed between 2000 and 2010 by using a nationwide all-payer inpatient sample conducted in collaboration with the Healthcare Cost and Utilization Project (n=93 801).[16] Approximately 50% of patients were aged ≥50 years, and a majority of participating institutes were characterized with having a large number of hospital beds and were teaching hospitals located in an urban environment. The overall complication rate was 6.29%, and they reported that there was a small (nonsignificant) rise in overall complication rate from 2000 (5.3%) to 2010 (7.5%). Cheng et al investigated complication rates and mortality between 2010 and 2015, and reported that there was a significant increase in quarterly rates of early mortality and procedural complications following CA for AF between 2010 and 2015.[14] It is speculated that these findings of increased mortality and complications may be related in part to a patient population that had more comorbidities (eg, 26.9% having ischemic heart disease).

The strengths of the present JROAD-DPC study are as follows: (1) the nationwide database used covered various cardiovascular hospitals in every region in Japan, (2) there was high accuracy of the DPC diagnoses and procedure codes to extract target subjects, (3) an analysis with detailed age groups (in 5-year increments) was performed, and (4) there was no patient selection bias with a large, unselected, and consecutive patient population. The uniqueness of the nationwide database may enable characterizing Japanese patients in comparison with data from the United States.

The prevalence of risk factors such as ischemic heart disease and female sex is lower in Japanese data compared with data from the United States, which may influence the lower complication rate found in Japan. The present finding of lower ischemic heart disease rates in Asian countries than in Western countries was consistent with a previous study based on statistics of the World Health Organization.[22] It is speculated that the decline in

population blood pressure level, decline in smoking rate, and lower serum total cholesterol level in Japan compared with North America and Europe may be related, in part, to the lower prevalence of ischemic heart disease in Japan.[23] Female sex is associated with lower cardiac mass, which may lead to a higher rate of complications such as cardiac perforation.[24] Racial differences might be also related to the difference in outcomes.

CA for AF in Older Patients

The safety of CA for AF, particularly for older patients, is attracting attention with progressive aging of the global population. There have been some studies (patient numbers of 4000–90 000) focused on the outcomes of AF ablation in older patients by using age cutoff of 70 years, 75 years, and 80 years, and those studies reported that complications following CA for AF was higher in older patients than younger patients.[16,25,26] There have been, however, few safety data on CA for AF in accordance with the detailed age groups. In the present study, we assessed the safety of CA for AF based on a real-world nationwide database of detailed age groups containing >135 000 patients. Older age was a particularly strong independent predictor of complications following CA for AF. Furthermore, this study showed that there was a stepwise increase in complication rate across the age groups when compared with the reference group (aged <60 years), and the increase in complication risk was found even in the 60 to 65 years age group. In addition, older patients had a higher prevalence of women, lower body mass index, a higher burden of comorbidities such as hypertension, and all of those characteristics were predictors for complications in the multivariate analysis. We also found that increased age was independently associated with the overall complications. We speculated that structural changes of myocardium with aging, independent of comorbidities, such as a stiffer, less compliant myocardium, made the heart vulnerable and might have influenced the results in this study.[27] From a safety point of view, it is important to determine the indication and strategies of CA for AF according to the patient's characteristics including age, sex, and comorbidities.

Study Limitations

The present study had some limitations. First, although the DPC data must be confirmed by a doctor and are highly reliable, some of data are based on medical claims. Therefore, there is a possibility that these data may contain certain errors, and some data may be over- or underestimated, although the accuracy of the JROAD-DPC is expected to be high as shown in our validation study (eg, some vascular access complications that have occurred with follow-up examinations might have be underestimated). Second, we investigated only the acute complications of CA; therefore, complications that occurred in the midterm, such as atrioesophageal fistula and pulmonary vein stenosis, could not be identified. As one of the characteristics of the DPC data set, if a patient goes to another hospital, he or she is assigned a different DPC identification. Therefore, it is not possible to follow-up on the same patients across different hospitals. Moreover, data about the technique, procedure time, type of AF (paroxysmal or persistent), time of onset of complications following CA for AF, and medications such as anticoagulants were not available.

CONCLUSIONS

The nationwide JROAD-DPC database demonstrated that the frequency of complications following CA for patients with AF increased according to age.

ARTICLE INFORMATION

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Disclosures

None.

Supplementary Material

Tables S1–S5
Figures S1–S3

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SUPPLEMENTAL MATERIAL

Table S1. ICD-10 Codes.

Variable	ICD-10 Codes
Cardiac complications	
Cardiac tamponade	I31.9, I97.1, J98.5, Procedure Codes: J048, J0021
Myocardial infarction	I21$, I22$, I23$
Vasospastic angina	I20.1
Complete atrioventricular block	I44.2
Sick sinus syndrome	I45.5, I49.5
Pacemaker implantation	Operation Codes: K5971, K5972
Pulmonary complications	
Pneumothorax	J930, J931, J938, J939
Hemothorax	J942
Pneumonia	J15.9, J18.9, J69.0
Neurological complications	
Phrenic nerve palsy	G58.8
Stroke or transient ischemic attack	G45$, I63$
Vascular access complications	
Hematoma	S701, S801, T140, T810
Pseudoaneurysm	I72.4
Other complications	
Thromboembolism	H342, I24, I269, I740, I741, I744, I748, I749, K550, K868, N280, T790
Blood transfusion	Operation Codes: K920, K9201-K9205
Cardiothoracic surgery	Operation Codes: K539

Table S2. Patient Characteristics in Each Age Group

Variable /aged	<60	60-64	65-69	70-74	75-79	80-84	≥85	P for trend
Number of patients	35,412	21,277	30,073	26,119	16,459	5,164	795	
Age, years	50.9±7.1	62.2±1.4	67.0±1.4	72.0±1.4	76.7±1.4	81.4±1.3	86.4±1.8	<0.001
Sex, female, n (%)	5,214 (14.7)	5,029 (23.6)	9,099 (30.3)	9,763 (37.4)	7,003 (42.5)	2442 (47.3)	402 (50.6)	<0.001
Height, cm	169.2±17.0	165.5±15.8	163.0±15.8	159.8±17.0	157.9±15.7	155.6±16.8	152.6±18.8	<0.001
Body weight, kg	72.9±15.0	67.7±12.9	64.4±12.1	61.4±11.7	59.4±12.5	56.9±10.9	54.1±10.7	<0.001
Body mass index	25.2±4.1	24.5±3.6	24.0±3.4	23.7±3.3	23.5±3.3	23.2±3.3	22.8±3.3	<0.001
Comorbidities								
Hypertension, n (%)	14,031 (39.6)	9,864 (46.4)	14,665 (48.8)	12,943 (49.6)	8,506 (51.7)	2,751 (53.3)	432 (54.3)	<0.001
Diabetes mellitus, n (%)	4,262 (12.0)	3,225 (15.2)	4,900 (16.3)	4,296 (16.4)	2,768 (16.8)	907 (17.6)	137 (17.2)	<0.001
Heart failure, n (%)	11,126 (31.4)	6,665 (31.3)	9,621 (32.0)	8,609 (33.0)	5,675 (34.5)	2,040 (39.5)	375 (47.2)	<0.001
NYHA class I, n (%)	2,672 (72.8)	1,559 (71.4)	2,152 (71.2)	1,751 (67.4)	1055 (64.6)	326 (59.0)	54 (54.0)	<0.001
II, n (%)	861 (23.4)	551 (25.2)	740 (24.5)	710 (27.3)	471 (28.8)	166 (30.0)	34 (34.0)	
III, n (%)	104 (2.8)	57 (2.6)	96 (3.2)	103 (4.0)	78 (4.8)	44 (7.9)	8 (8.0)	
IV, n (%)	35 (1.0)	17 (0.8)	36 (1.2)	33 (1.3)	30 (1.8)	17 (3.1)	4 (4.0)	
Stroke or TIA, n (%)	393 (1.1)	284 (1.3)	445 (1.5)	436 (1.7)	253 (1.5)	87 (1.7)	14 (1.8)	<0.001
Ischemic heart disease, n (%)	3,917 (11.1)	2,802 (13.2)	4,427 (14.7)	4,209 (16.1)	2,978 (18.1)	1,098 (21.3)	169 (21.3)	<0.001
CHA_2DS_2-VASc score	1 [0 - 2]	1 [1 - 2]	2 [2 - 3]	2 [2 - 3]	3 [3 - 4]	4 [3 - 4]	4 [3 - 4]	<0.001
$CHADS_2$ score	1 [0 - 1]	1 [0 - 2]	1 [0 - 2]	1 [0 - 2]	2 [1 - 3]	2 [2 - 3]	2 [2 - 3]	<0.001
Cryoballoon, n (%)	4,805 (13.6)	2,620 (12.3)	4,026 (13.4)	3,532 (13.5)	2,450 (14.9)	947 (18.3)	192 (24.2)	<0.001

TIA = indicates transient ischemic attack, NYHA = New York Heart Association

Table S3. Univariate Logistic Regression Analysis of the Mortality.

Variable	Univariate	
	OR (95% CI)	P value
Age	1.05 (1.02-1.09)	0.001
Sex (female)	2.21 (1.29-3.80)	0.004
BMI	0.86 (0.79-0.94)	0.001
Hypertension	0.72 (0.41-1.26)	0.249
Diabetes mellitus	1.81 (0.96-3.39)	0.065
Heart failure	1.90 (1.09-3.30)	0.023
Stroke or TIA	2.72 (0.65-11.32)	0.169
Prior myocardial infarction	1.58 (0.22-11.50)	0.649

BMI indicates body mass index; TIA, transient ischemic attack; OR, odds ratio; CI, confidence interval

Table S4. In-hospital Complications in Each Age Group

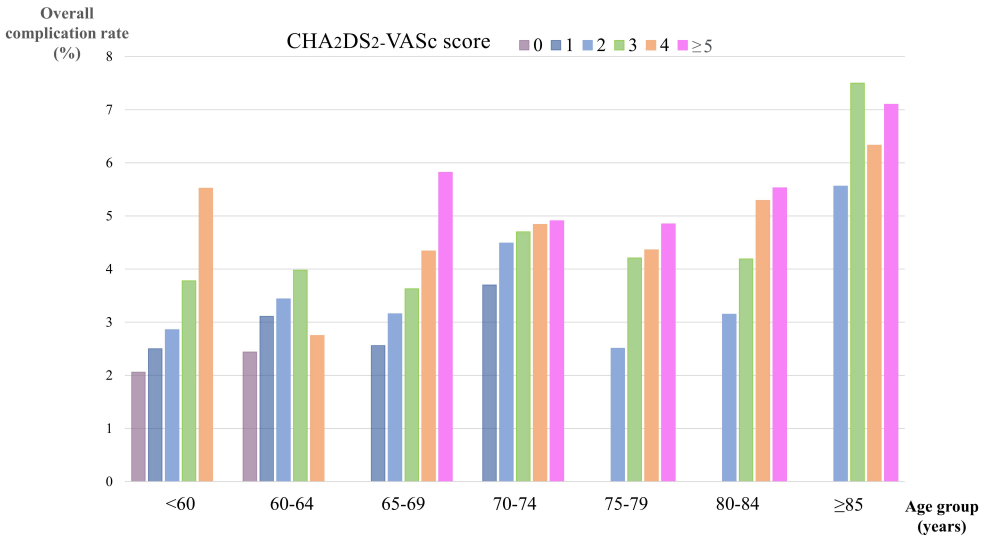
Variable /aged	<60	60-64	65-69	70-74	75-79	80-84	≥85	P for trend
Number of patients	35,412	21,277	30,073	26,119	16,459	5,164	795	
Overall complications, n (%)	893 (2.5)	662 (3.1)	1,003 (3.3)	1,060 (4.1)	678 (4.1)	244 (4.7)	54 (6.8)	<0.001
Cardiac complications								
Cardiac tamponade, n (%)	274 (0.8)	222 (1.0)	370 (1.2)	379 (1.5)	253 (1.5)	108 (2.1)	14 (1.8)	<0.001
Myocardial infarction, n (%)	23 (<0.1)	18 (<0.1)	30 (0.1)	28 (0.1)	19 (0.1)	4 (<0.1)	0 (0)	0.108
Vasospastic angina, n (%)	20 (<0.1)	13 (<0.1)	26 (<0.1)	22 (<0.1)	14 (<0.1)	4 (<0.1)	1 (0.1)	0.120
Complete AVB, n (%)	19 (<0.1)	10 (<0.1)	20 (<0.1)	18 (<0.1)	11 (<0.1)	4 (<0.1)	2 (0.3)	0.133
Sick sinus syndrome, n (%)	56 (0.2)	52 (0.2)	110 (0.4)	118 (0.5)	105 (0.6)	39 (0.8)	11 (1.4)	<0.001
Pacemaker implantation, n (%)	58 (0.2)	89 (0.4)	205 (0.7)	243 (0.9)	177 (1.1)	74 (1.4)	14 (1.8)	<0.001
Pulmonary complications								
Pneumothorax, n (%)	11 (<0.1)	4 (<0.1)	6 (<0.1)	9 (<0.1)	7 (<0.1)	0 (0)	1 (0.1)	0.591
Hemothorax, n (%)	5 (<0.1)	2 (<0.1)	2 (<0.1)	4 (<0.1)	6 (<0.1)	0 (0)	0 (0)	0.365
Pneumonia, n (%)	89 (0.3)	55 (0.3)	61 (0.2)	79 (0.3)	64 (0.4)	20 (0.4)	10 (1.3)	<0.001
Neurological complications								
Phrenic nerve palsy, n (%)	10 (<0.1)	3 (<0.1)	12 (<0.1)	12 (<0.1)	9 (<0.1)	2 (<0.1)	1 (0.1)	0.037
Stroke or TIA, n (%)	296 (0.8)	237 (1.1)	278 (0.9)	304 (1.2)	150 (0.9)	49 (0.9)	11 (1.4)	0.052
Vascular access complications								
Hematoma, n (%)	49 (0.1)	27 (0.1)	51 (0.2)	49 (0.2)	31 (0.2)	8 (0.2)	1 (0.1)	0.098
Pseudoaneurysm, n (%)	16 (<0.1)	17 (0.1)	24 (0.1)	23 (0.1)	22 (0.1)	4 (0.1)	1 (0.1)	0.004
Other complications								
Thromboembolism, n (%)	68 (0.2)	36 (0.2)	67 (0.2)	77 (0.3)	31 (0.2)	14 (0.3)	6 (0.8)	0.014
Length of stay, days	5 [4 - 6]	5 [4 - 6]	5 [4 - 6]	5 [4 - 7]	5 [4 - 7]	5 [4 - 8]	5 [4 - 9]	<0.001
In-hospital death, n (%)	6 (<0.1)	6 (<0.1)	8 (<0.1)	16 (<0.1)	11 (<0.1)	5 (0.1)	1 (0.1)	<0.001

AVB = atrioventricular block, TIA = transient ischemic attack

Table S5. Univariate Logistic Regression Analyses of the Overall Complications for stratified CHA_2DS_2-VASc score 3, 4, and ≥ 5

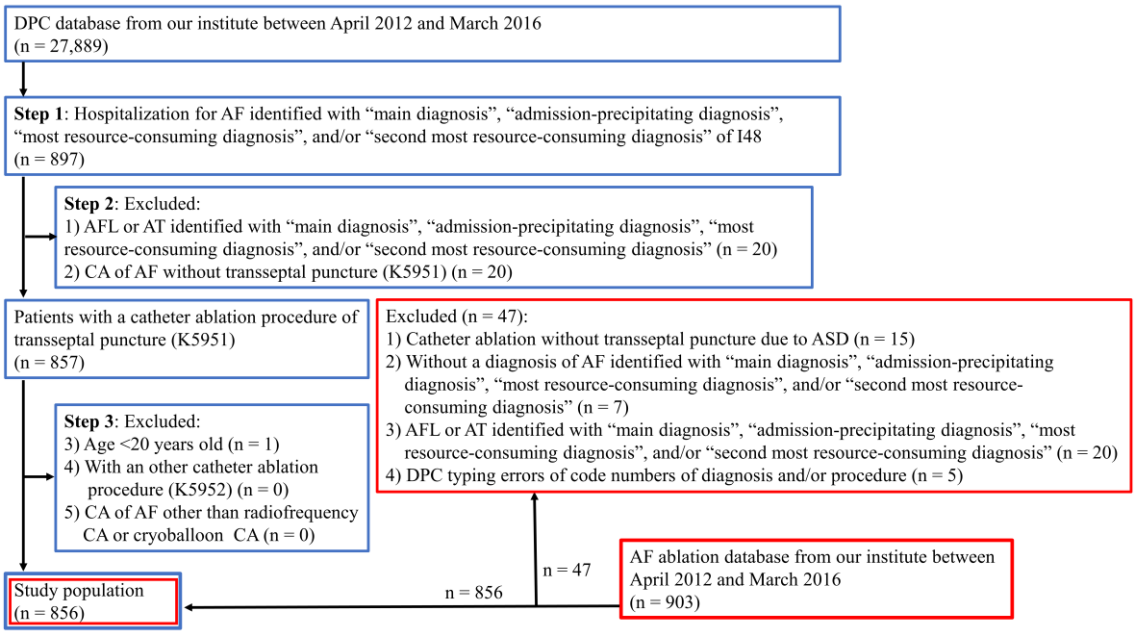
Variable	Univariate	
	OR (95% CI)	P value
CHA_2DS_2-VASc score = 3		
Age	1.01 (1.00-1.02)	0.007
Age (reference, <60 years)		
60-64	1.07 (0.76-1.52)	0.690
65-69	0.97 (0.74-1.27)	0.825
70-74	1.21 (0.92-1.58)	0.172
75-79	1.18 (0.89-1.56)	0.253
80-84	1.20 (0.85-1.69)	0.307
≥85	2.32 (1.33-4.04)	0.003
P=0.020 for trend		
CHA_2DS_2-VASc score = 4		
Age	1.01 (1.00-1.03)	0.174
Age (reference, <60 years)		
60-64	0.45 (0.15-1.37)	0.160
65-69	0.70 (0.35-1.39)	0.310
70-74	0.76 (0.39-1.51)	0.441
75-79	0.69 (0.35-1.35)	0.276
80-84	0.88 (0.44-1.77)	0.725
≥85	1.04 (0.46-2.39)	0.918
P=0.181 for trend		
CHA_2DS_2-VASc score ≥ 5		
Age	1.00 (0.97-1.03)	0.836
Age (reference, <60 years)		
60-64	-	-
65-69	0.83 (0.40-1.73)	0.628
70-74	0.68 (0.32-1.42)	0.301
75-79	0.66 (0.36-1.21)	0.178

Figure S1. Overall complication rate in each age group according to CHA_2DS_2-VASc score.



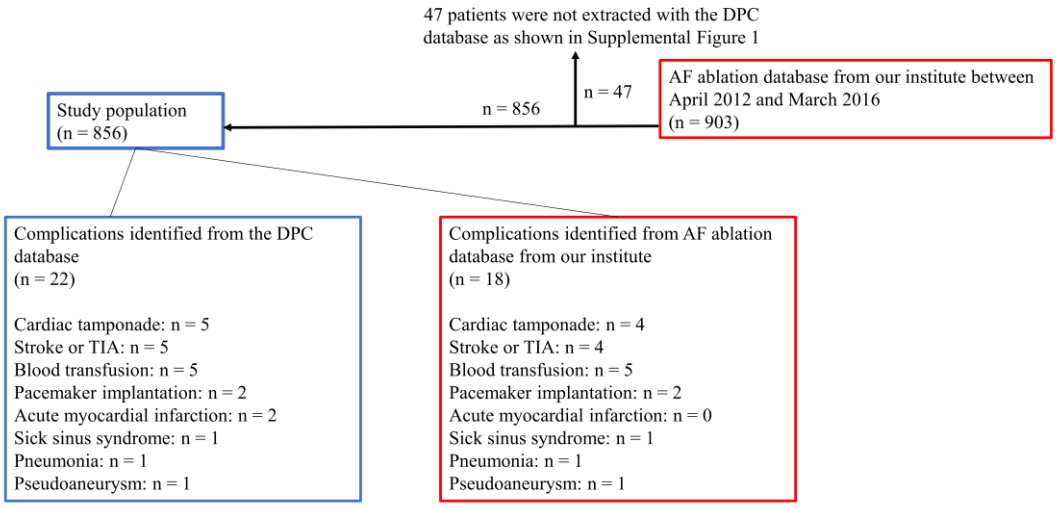
In most each age group, the overall complication rate increased according to the CHA_2DS_2-VASc score.

Figure S2. Flowchart of the pilot study to examine the accuracy of the DPC database to extract patients who underwent CA of AF.



DPC indicates Diagnosis Procedure Combination; ICD, International Classification of Disease; CA, catheter ablation; AF, atrial fibrillation; AFL, atrial flutter; AT, atrial tachycardia.

Figure S3. Flow diagram of the pilot study to examine the accuracy of the DPC database to extract patients who had complication following CA of AF.



DPC indicates Diagnosis Procedure Combination; ICD, International Classification of Disease; CA, catheter ablation; AF, atrial fibrillation; TIA, transient ischemic attack.

80-84	0.75 (0.39-1.42)	0.374
≥85	-	-
	P=0.539 for trend	

OR, odds ratio; CI, confidence interval