Published in final edited form as:

J Cardiovasc Electrophysiol. 2017 January ; 28(1): 39–48. doi:10.1111/jce.13118.

Safety and Clinical Outcomes of Catheter Ablation of Atrial Fibrillation in Patients with Chronic Kidney Disease

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Abstract

INTRODUCTION—Data regarding catheter ablation of atrial fibrillation (AF) in patients with chronic kidney disease (CKD) is limited. We therefore assessed the association of CKD with common safety and clinical outcomes in a nationwide sample of ablation recipients.

METHODS—Using MarketScan[®] Commercial Claims and Medicare Supplemental Databases, we evaluated 30-day safety and 1-year clinical outcomes in patients who underwent a first AF ablation procedure between 2007–2011. We calculated frequency of common 30-day complications and calculated frequencies, incidence rates, and Cox proportional hazards for outcomes at 1 year post-ablation.

RESULTS—Of 21,091 patients included, 1,593 (7.6%) had CKD. Patients with CKD were older (64 vs 59 years, $p<0.001$) with higher CHA₂DS₂-VASc scores (3.2 vs 1.8, $p<0.001$). At 30 days post-ablation, patients with CKD had similar rates of stroke/TIA (0.13% vs 0.13%, $p=0.99$), perforation/tamponade (3.2% vs 3.1%, $p=0.83$), and vascular complications (2.4% vs 2.2%, $p=0.59$) as patients without CKD, but were more likely to be hospitalized for heart failure (2.1%

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Disclosures:

WCW serves on an event adjudication committee for Medtronic. JPP receives grants for clinical research from ARCA biopharma, Boston Scientific, Gilead, Janssen Pharmaceuticals, ResMed, and St Jude Medical and serves as a consultant to Bayer, Johnson & Johnson, Medtronic, and Spectranetics. MPT receives grants for clinical research from Medtronic, SentreHeart, Gilead Sciences Cardiovascular Scholars Program, Janssen Pharmaceuticals, JT Stroke Shield Foundation, and the Veterans Health Administration and serves as a consultant to Medtronic and St Jude Medical.

vs. 0.4%, $p<0.001$). In multivariate analysis, there were no significant differences in hazards of AF hospitalization (adjusted HR: 1.02, 95%CI: 0.87–1.20), cardioversion (adjusted HR: 0.99, 95%CI: 0.87–1.12), or repeat AF ablation (adjusted HR: 0.89, 95%CI: 0.76–1.06) at one year.

CONCLUSIONS—Among patients selected for AF ablation, those with and without CKD had similar rates of post-procedural complications although they were more likely to be re-admitted for heart failure. CKD was not independently associated with AF hospitalization, cardioversion, and repeat ablation. These findings can inform clinical decision-making in patients with AF and CKD.

Keywords

atrial fibrillation; chronic kidney disease; safety; catheter ablation; stroke

INTRODUCTION

Atrial fibrillation (AF) and chronic kidney disease (CKD) are common comorbid conditions with a complex relationship.^{1,2} In addition to sharing common risk factors such as increased age, hypertension, and diabetes, presence of CKD independently increases the risk for development of AF.³ Patients with CKD and AF are also at increased risk of stroke and anticoagulation-associated hemorrhage.^{4,5} Furthermore, AF may accelerate deterioration of kidney function⁶, while maintenance of sinus rhythm may preserve or improve it.⁷

A recent European Heart Rhythm Association position paper highlights the current evidence gap regarding management of AF in the context of CKD.⁸ As most large AF studies exclude patients with functionally significant kidney disease³, there is limited data regarding safety of agents commonly used for rate and rhythm control.⁸ Consequently, catheter-based AF ablation is an attractive treatment option for AF patients with CKD. However, only small studies from Japan and China (16 to 232 patients)^{9–13} have examined AF ablation in CKD cohorts, suggesting a high rate of AF recurrence after ablation, but with few insights into other post-procedural outcomes. We therefore performed a retrospective cohort study using commercial health insurance claims of U.S. patients undergoing catheter ablation for AF to report the associations of CKD with common 30-day complications and one-year clinical outcomes.

METHODS

We analyzed data from the Truven Health MarketScan Commercial Claims and Encounters and Medicare Supplemental Databases (Truven Health Analytics Inc., Ann Arbor, MI). Linked and merged datasets included the Inpatient Admissions file, which contains all diagnoses and procedures in the service records related to a hospital admission; the Outpatient Services file, which contains information on encounters and claims for services delivered at a doctor's office, hospital outpatient facility, emergency room, or other outpatient facility; and the Outpatient Pharmaceutical Claims file, which includes complete records of mail-order or card program prescription drug claims. The study was approved by the local Institutional Review Board prior to analysis.

We identified all adult patients with non-valvular AF who received a catheter ablation between January 1, 2007 and December 31, 2011 (Figure 1). Patients were required to have a primary diagnosis of AF (*International Classification of Diseases, 9th Revision* [ICD-9] code 427.31) associated with any inpatient or outpatient encounter as well as a documented catheter ablation procedure (ICD-9 code 37.34 or *Current Procedural Terminology, 4th Edition* [CPT-4] code 93651). Additionally, all patients were required to have continuous insurance enrollment in the MarketScan databases for at least six months prior and one month after the index ablation date.

Primary predictor, complications, and outcomes

The primary predictor was presence of chronic kidney disease up to one year prior to the catheter ablation date. The following ICD-9 codes were selected after review and comparison with other published definitions of CKD¹⁴: ICD-9 codes 250.4, 403.01, 403.11, 403.91, 404.02, 404.12, 404.92, 404.03, 404.13, 404.93, 590.0, 590.00, 590.01, 590.8, 590.80, 593.9, 753.12, 753.13, 753.14, 753.15, 753.16, 753.17, 753.19, 58.2, 58.3, 58.4, 58.5, 58.6, 58.7, and 58.8. These diagnostic codes were chosen to be specific to CKD to in order to avoid misclassification of non-CKD patients as those with CKD. We did not use codes for acute kidney injury. Previous work has shown that this selected strategy has a sensitivity of 0.52, specificity of 0.99, positive predictive value of 0.32, and negative predictive value of 0.99 for comorbidity ascertainment in the context of cardiovascular procedures.^{14,15}

We assessed the safety of AF ablation using 30-day post-procedural complications based on common diagnosis and procedure codes identified by previous investigators.^{16,17} These included all-cause hospitalizations, vascular complications, hematoma or hemorrhage, cardiac perforation or tamponade, pneumothorax or hemothorax, stroke or transient ischemic attack (TIA), pacemaker implantation, implantable cardioverter defibrillator (ICD) implantation, heart failure (HF), and in-hospital death. For all-cause hospitalizations, we searched inpatient datasets for any admissions occurring in the 30 days after the index ablation. For all other 30 day complications, we searched for relevant ICD-9 and CPT-4 codes in the inpatient dataset within the first 30 days of the ablation date.

We also evaluated the following clinical outcomes: time to hospitalization for AF, time to cardioversion, and time to repeat ablation in the first year after index catheter AF ablation. For the endpoint of AF hospitalization, we considered any inpatient encounter associated with a primary diagnosis for AF, which occurred after the initial inpatient or outpatient AF ablation procedure. Cardioversion and repeat ablation for AF at one year were ascertained based on CPT-4 codes for each procedure in both inpatient and outpatient datasets. Secondary outcomes at one year included hospitalization for all-causes, myocardial infarction (MI) or unstable angina, HF, supraventricular tachycardia, ventricular arrhythmia, stroke/TIA, intracranial hemorrhage, and syncope.

Clinical covariates

Patient baseline comorbidities were determined using comorbidity-specific ICD-9 codes up to one year prior to the catheter ablation date, based on the Agency for Healthcare Research

and Quality (AHRQ) Clinical Classification System.⁴ We additionally assessed comorbidity using the Charlson and Selim Comorbidity Indices and assessed stroke risk using the CHADS₂ and CHA₂DS₂-VASc scores. Pharmacological therapies received in the 120 days prior to AF ablation were ascertained using the MarketScan[®] Outpatient Pharmaceutical Claims file.

Statistical analysis

We compared differences in baseline characteristics and 30-day complications between CKD and non-CKD groups using t-tests for continuous variables and chi-squared tests and Fisher's exact tests for categorical variables. For all primary and secondary outcomes at 1 year, we calculated incidence rates for the first event in each patient by dividing the number of events by total person-years of follow-up for each group.

Cox proportional hazards regression was used to examine the association between CKD and each outcome at 1 year. In the full multivariate model, we adjusted for age, sex, Charlson Comorbidity Index score, HF, hypertension, diabetes, stroke/TIA, prior MI, anemia, peripheral artery disease (PAD) or vascular disease, chronic obstructive pulmonary disease (COPD), sleep apnea, year of ablation, insurance plan, and receipt of concomitant drug therapies (warfarin, dabigatran, clopidogrel, Class I and Class III anti-arrhythmic drugs, amiodarone, beta blockers, and calcium channel blockers). We also used the Kaplan-Meier method and Log-rank tests to calculate differential probability of event-free survival using the composite endpoint of AF hospitalization, cardioversion, or repeat AF ablation within one year. All analyses were performed using SAS, version 9.1 (Cary, NC) and STATA, version 11.0 (College Station, TX).

RESULTS

The study cohort included 21,091 patients (59.2 ± 10.9 years, 73.7% with age <65 years) that received a catheter ablation for AF between 2007 and 2011; 29.1% were women and 7.6% had a diagnosis code for CKD. There were 61 patients on dialysis. Ablation recipients with CKD were older than those without kidney disease (64 vs. 59 years, $p<0.001$; Table 1), driven by a larger proportion of CKD patients who were 65–80 years old (34.3% of CKD patients vs. 22.7% in non-CKD, $p<0.001$) and >80 years old (7.0% vs. 2.2%, $p<0.001$).

The prevalence of baseline comorbidities such as HF, hypertension, diabetes, prior stroke/TIA, PAD, COPD, and obstructive sleep apnea were higher in patients with CKD, which contributed to higher mean scores on both the Charlson (2.7 vs. 0.92, $p<0.001$) and Selim (5.3 vs. 2.5, $p<0.001$) Comorbidity Indices. Patients with CKD also had higher mean CHADS₂ (1.9 vs. 1.0, $p<0.001$) and CHA₂DS₂-VASc (3.2 vs. 1.8, $p<0.001$) scores compared to patients without CKD. At baseline, the proportion of patients receiving class I and class III anti-arrhythmic drugs was smaller in patients with CKD, but the proportion of patients receiving amiodarone, statins, diuretics, and ACE-inhibitors or angiotensin receptor blockers was greater in patients with CKD. Receipt of systemic anticoagulants (warfarin, dabigatran, rivaroxaban) at baseline were slightly lower in patients with CKD (63% vs 68%, $p<0.001$).

30-day complications

Seven patients (0.03%) experienced an in-hospital death within 30 days of the index AF ablation, with no significant differences in risk of in-hospital death in patients with or without CKD (Table 2). Rates of vascular complications, hematoma/hemorrhage, stroke/TIA, and cardiac perforation or tamponade were similar in both groups, but heart failure admissions were more common in CKD patients (2.1% vs. 0.4%, $p<0.001$). All-cause hospitalization within 30 days was more common in patients with CKD (12.9% vs. 8.5%, $p<0.001$).

Cause-specific hospitalizations and outcomes at one year

Patients with CKD had a higher incidence rate and hazard of all-cause hospitalization at one year than those without CKD (Table 3). However, the hazards of AF hospitalization (unadjusted HR: 1.09, 95% CI: 0.95–1.26, $p=0.21$; adjusted HR: 1.02, 95% CI: 0.87–1.20, $p=0.79$) and cardioversion (unadjusted HR: 1.12, 95% CI: 0.99–1.24, $p=0.07$; adjusted HR: 0.99, 95% CI: 0.87–1.12, $p=0.87$; Table 3) were not significantly higher in patients with CKD. The unadjusted hazard of repeat ablation for AF was significantly lower in patients with CKD (unadjusted HR: 0.82, 95% CI: 0.70–0.95 $p=0.008$) but the association was not significant after adjusting for baseline comorbidities and concomitant therapies in the full multivariate model (adjusted HR: 0.89, 95% CI: 0.76–1.06, $p=0.18$).

Table 4 shows incidence rates and hazards of secondary outcomes at one year post-ablation. The hazards of stroke/TIA did not significantly differ between CKD and non-CKD groups (unadjusted HR: 1.71, 95% CI: 0.96–3.05, $p=0.07$; adjusted HR: 0.95, 95% CI: 0.48–1.87, $p=0.88$; Table 4). However, there were higher unadjusted hazards of hospitalization for all-causes, myocardial infarction/unstable angina, HF, supraventricular tachycardia, ventricular arrhythmia, and intracranial hemorrhage in patients with CKD. After adjusting for baseline comorbidities and drug therapies, patients with CKD were found to have higher hazards of all-cause hospitalization (adjusted HR 1.19, 95%CI: 1.09–1.31, $p<0.001$; Table 3) and hospitalization for heart failure (adjusted HR: 2.26, 95%CI: 1.74–2.94, $p<0.001$; Table 4). There were no significant differences in adjusted hazards for MI/unstable angina, supraventricular tachycardia, ventricular arrhythmia, and intracranial hemorrhage between patients with CKD and those without CKD. Cumulative event-free survival, defined as freedom from AF rehospitalization, cardioversion, or repeat AF ablation, was similar based on presence of CKD. Finally, we compared differences in survival free from AF hospitalization, cardioversion, or repeat AF ablation at one year. There was no significant difference in event-free survival based on presence of CKD (Log-rank $p=0.62$; Figure 2)

DISCUSSION

In this claims cohort analysis of AF ablation in patients with and without chronic kidney disease, we found that patients with CKD experienced similar 30-day complications such as stroke/TIA, perforation/tamponade, and vascular complications but were more likely to be admitted for heart failure. Prior to our analysis, most large studies on AF ablation recipients examined older cohorts and did not measure safety in the context of CKD. These studies have suggested a higher rate of major complications ranging from 5% to 9.1% based on

Medicare claims and the California State Inpatient Database.^{18–20} More recently, Deshmukh *et al.*¹⁷ used data from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) and studied inpatient ablations in 93,801 patients, in whom the overall complication rate was 6.29%. AHRQ has previously noted inconsistencies and incomplete coding for observational services in HCUP data²¹, which could result in ascertainment bias because outpatient encounters are excluded, person-level linkage cannot be performed, and the unit of observation is hospitalization. In contrast, our datasets included full patient-level data from inpatient and outpatient ablations and suggested lower complication rates in patients with and without CKD. There were notably no significant differences in risk of cardiac tamponade with presence of CKD, often cited as the most common ablation-related complication.²² In-hospital deaths were also infrequent in our cohort (0.03%), similar to rates reported in earlier studies^{18–20}, with no significant differences between CKD and non-CKD patient groups.

At one year post-ablation, our study found an increased risk of all-cause hospitalization in CKD patients, but no increase in risk of AF hospitalization, cardioversion, or repeat AF ablation. Prior to our study, only small retrospective cohort studies have examined clinical outcomes after AF ablation in the context of CKD. In three studies, kidney dysfunction was an independent predictor of AF recurrence upon ECG or Holter recordings conducted at 3-month intervals.^{9–11} A meta-analysis combining these data reported a significant association between an estimated glomerular filtration rate (eGFR) <60 mL/min/1.73m² and AF recurrence with at least 1 year of follow-up (pooled HR: 2.32, 95%CI: 1.61–3.35, $p<0.001$).²³ Another study examining 702 ablation recipients reported an association between CKD and AF recurrence using a cutpoint of eGFR <68 mL/min/1.73m² (HR: 1.43, 95%CI: 1.05–1.95, $p=0.007$).²⁴ Given limitations in our data, we could not directly assess post-ablation AF recurrence in our cohort, but measured health care utilization associated with AF recurrence after the ablation procedure.

At both 30 days and 1-year, admission for heart failure was more common in ablation recipients with CKD. Congestive heart failure has been increasingly recognized as an acute sequela after AF ablation and may be due to fluid overload in the setting of a noncompliant atrium, poor left atrial function, or diastolic dysfunction.^{25–27} A reduction in fluid delivery with use of low-volume irrigated-tip catheters may have promise in reducing HF complications associated with volume overload, as would tools or techniques that can reduce overall procedure time.^{12,13} On the other hand, impaired renal function is itself a risk factor for both HF and HF hospitalization^{6,7} and higher hospitalization rates could reflect the higher prevalence of HF in the CKD group at baseline, or at least the propensity to retain fluid.

Limitations

Our study has important limitations. These data predated the introduction of CPT codes specific to ablation for AF. Although our algorithm represents a high-specificity approach, it is possible that some ablations could have been performed for arrhythmias other than AF. CKD was ascertained by ICD-9 codes, which could result in misclassification of CKD patients as non-CKD patients and bias results toward the null. Our data sources did not allow

us to categorize AF severity (e.g paroxysmal vs persistent) or to directly measure kidney function. We also could not consider the role of novel oral anticoagulants given the time period of our study. Data regarding periprocedural anticoagulation were limited because claims data capture only prescriptions filled and cannot ascertain cessation or interruption of periprocedural anticoagulation. Finally, our study is restricted to patients with AF who underwent ablation, but does not provide information on who among AF patients was selected for ablation. It is therefore possible that among those with CKD only relatively healthier patients were selected as suitable candidates for the procedure, resulting in confounding by treatment selection. However, it was notable that a significantly higher proportion of older patients (65–80 and >80) received an AF ablation in the CKD patient group compared to the non-CKD group.

CONCLUSIONS

Among U.S. patients selected for AF ablation, patients with CKD, compared to those without CKD, were found to have similar rates of common procedural complications, but were more likely to be admitted for heart failure at 30-days and at one year. CKD was not independently associated with AF hospitalization, cardioversion, and repeat ablation.

Acknowledgments

FUNDING SOURCES: Supported by a Veterans Health Services Research & Development Career Development Award (CDA09027-1), an American Heart Association National Scientist Development Grant (09SDG2250647), a National Institute for Diabetes and Digestive and Kidney Diseases Grant (R01 DK095024), and a grant from the Gilead Sciences Research Scholars Program in Cardiovascular Disease. The sponsors were not involved with study design, data assembly and analysis, or manuscript preparation.

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Fig 1.
Shows inclusion and exclusion criteria used to select the final analysis cohort of 21,091 patients
Flow Diagram.

Fig 2.

Differential probability of event-free survival was determined using the Kaplan-Meier method. In the CKD group, 69.18% of patients were free from a first AF hospitalization, cardioversion, or repeat ablation (composite endpoint) at one year, compared to 68.95% of patients in the non-CKD group. Differences in event-free survival were assessed using the Log-rank test.

Survival free from AF hospitalization, cardioversion, or repeat ablation.

Table 1

Baseline Characteristics.

	Chronic Kidney Disease (CKD) Status		p
	CKD (N=1,593)	No CKD (N=19,498)	
Inpatient/Outpatient Status			0.11
Inpatient	658 (41.3%)	7,653 (39.3%)	
Outpatient	935 (58.7%)	11,845 (60.8%)	
Age, years	64.0 ± 10.6	58.8 ± 10.8	<0.001
Age group, years			<0.001
<18	0 (0.0%)	28 (0.14%)	
18–34	8 (0.5%)	430 (2.2%)	
35–49	113 (7.1%)	2,809 (14.4%)	
50–64	816 (51.2%)	11,350 (58.2%)	
65–80	546 (34.3%)	4,428 (22.7%)	
>80	110 (7.0%)	453 (2.3%)	
Sex			0.14
Female	489 (30.7%)	5,648 (29.0%)	
Male	1,104 (69.3%)	13,850 (71.0%)	
Comorbidity index			
Charlson comorbidity index	2.7 ± 1.7	0.92 ± 1.1	<0.001
Selim comorbidity index	5.3 ± 2.7	2.5 ± 2.0	<0.001
CHADS₂ score	1.9 ± 1.2	1.0 ± 1.0	<0.001
CHADS₂ score group			<0.001
CHADS₂ 0	168 (10.6%)	6,759 (34.7%)	
CHADS₂ 1	473 (30.0%)	7,846 (40.2%)	
CHADS₂ 2	482 (30.3%)	3,311 (17.0%)	
CHADS₂ 3	305 (19.1%)	1,163 (6.0%)	

	Chronic Kidney Disease (CKD) Status		<i>p</i>
	CKD (N=1,593)	No CKD (N=19,498)	
CHADS ₂ 4	96 (6.0%)	315 (1.6%)	
CHADS ₂ 5	56 (3.5%)	90 (0.46%)	
CHADS ₂ 6	13 (0.8%)	14 (0.07%)	
CHA ₂ DS ₂ -VASC score	3.2 ± 1.8	1.8 ± 1.5	<0.001
Heart failure	911 (57.2%)	6,158 (31.6%)	<0.001
Hypertension	1,337 (83.9%)	11,970 (61.4%)	<0.001
Diabetes	672 (42.2%)	3,825 (19.6%)	<0.001
Prior stroke or transient ischemic attack	123 (7.7%)	753 (3.9%)	<0.001
Prior myocardial infarction	167 (10.5%)	940 (4.8%)	<0.001
Anemia	489 (30.7%)	1,575 (8.1%)	<0.001
Prior bleeding	395 (21.9%)	2,297 (9.6%)	<0.001
Peripheral artery disease	180 (11.3%)	727 (3.7%)	<0.001
Dialysis	61 (3.83%)	0 (0.0%)	<0.001
Chronic obstructive pulmonary disease	348 (21.9%)	1,898 (9.73%)	<0.001
Obstructive Sleep Apnea	438 (27.5%)	4,149 (21.3%)	<0.001
Region			0.30
Northeast	216 (13.6%)	2,742 (14.1%)	
North Central	463 (29.1%)	5,375 (27.6%)	
South	613 (38.4%)	7,713 (39.3%)	
West	271 (17.0%)	3,402 (17.5%)	
Unknown	30 (1.9%)	266 (1.4%)	
Ablation Year			<0.001

Chronic Kidney Disease (CKD) Status			
	CKD (N=1,593)	No CKD (N=19,498)	p
2007	148 (9.3%)	2,308 (11.8%)	
2008	203 (12.7%)	2,919 (15.0%)	
2009	240 (15.1%)	3,432 (17.6%)	
2010	384 (24.1%)	4,356 (22.3%)	
2011	618 (38.8%)	6,484 (33.3%)	
Insurance Plan Type			<0.001
Comprehensive	313 (20.0%)	2,373 (12.2%)	
EPO	22 (1.4%)	261 (1.3%)	
HMO	159 (10.0%)	2,111 (10.8%)	
POS	82 (5.2%)	1,260 (6.5%)	
PPO	873 (54.8%)	11,741 (60.2%)	
POS with capitation	9 (0.56%)	105 (0.54%)	
CDHP	30 (1.9%)	479 (2.5%)	
HDHP	10 (0.63%)	236 (1.2%)	
Missing	95 (6.0%)	932 (4.8%)	
Cardiovascular medications			
Aspirin	2 (0.13%)	45 (0.23%)	0.39
Warfarin	872 (54.7%)	11,204 (57.5%)	0.04
Dabigatran	130 (8.2%)	1,978 (10.1%)	0.01
Rivaroxaban	0 (0.0%)	3 (0.02%)	1.00
Clopidogrel	135 (8.5%)	1,066 (5.5%)	<0.001
ACE inhibitor or angiotensin receptor blocker	639 (40.1%)	6,253 (32.1%)	<0.001
Diuretics	676 (42.4%)	4,991 (25.6%)	<0.001
Niacin or fibrates	69 (4.3%)	605 (3.1%)	0.007
Statins	534 (33.5%)	5,239 (26.9%)	<0.001
Antiarrhythmic drugs			
All Class I	243 (15.3%)	5,036 (25.8%)	<0.001
Class III (Sotalol/Dofetilide)	223 (14.0%)	3,983 (20.4%)	<0.001

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Chronic Kidney Disease (CKD) Status			
	CKD (N=1,593)	No CKD (N=19,498)	<i>p</i>
Amlodarone	343 (21.5%)	2,894 (14.8%)	<0.001
Rate-controlling drugs			
Metoprolol	507 (31.8%)	6,147 (31.5%)	0.80
Carvedilol	227 (14.2%)	1,304 (6.7%)	<0.001
Atenolol	82 (5.2%)	1,203 (6.2%)	0.10
Calcium-channel blockers			
Diltiazem	311 (19.5%)	3,462 (17.8%)	0.08
Verapamil	32 (2.0%)	487 (2.5%)	0.22

Table 2

30-Day complications after AF ablation.

30-Day complications	All patients (N=21,091)	Chronic Kidney Disease (CKD) Status		
		CKD (N=1,593)	No CKD (N=19,498)	p
All-cause hospitalization [any admission in Inpatient Admissions file between t+1 and t+30 days after ablation]	1,868 (8.9%)	209 (12.9%)	1,659 (8.5%)	<0.001
Vascular complication [ICD-9 codes: 998.11, 998.12, 998.2, 39.31, 39.41, 39.49, 39.52, 39.53, 39.56, 39.57, 39.58, 39.59, 39.79]	463 (2.2%)	38 (2.4%)	425 (2.2%)	0.59
Blood Transfusion [ICD-9 codes: 99.03, 99.04 and CPT-4 code: 36430]	115 (0.55%)	26 (1.63%)	89 (0.46%)	<0.001
Hematoma or hemorrhage [ICD-9 codes: 998.11, 998.12]	376 (1.8%)	32 (2.0%)	344 (1.8%)	0.48
Perforation or tamponade [ICD-9 codes: 37.0, 423.0, 423.3, 423.9]	656 (3.1%)	51 (3.2%)	605 (3.1%)	0.83
Pneumothorax or hemothorax [ICD-9 code: 340.4, 512.0, 512.1, 511.8, 512.8]	29 (0.14%)	4 (0.25%)	25 (0.13%)	0.27
Stroke or transient ischemic attack [ICD-9 codes: 434.0x, 434.1x, 434.9x, 435.9]	27 (0.13%)	2 (0.13%)	25 (0.13%)	1.00
Pacemaker implantation [ICD-9 codes: 00.50, 00.52, 00.53, 37.71, 37.72, 37.73, 37.74, 37.75, 37.76, 37.77, 37.78, 37.79, 37.81, 37.82, 37.83, 37.84, 37.85, 37.86, 37.87, 37.88, 37.89]	124 (0.59%)	16 (1.0%)	108 (0.55%)	0.02
Implantable cardioverter defibrillator implantation [ICD-9 codes: 37.94, 37.95, 37.96, 37.97, 37.98, 00.51, 00.54]	16 (0.08%)	2 (0.13%)	14 (0.07%)	0.34
Heart failure [ICD-9 codes: 398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.0, 425.1, 425.2, 425.3, 425.4, 425.5, 425.7, 425.8, 425.9, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9, 429.3]	116 (0.55%)	34 (2.1%)	82 (0.4%)	<0.001
In-hospital Death [Discharge Status file codes: 20, 21]	7 (0.03%)	1 (0.06%)	6 (0.03%)	0.42

Table 3

Primary outcomes in one year after initial ablation (N=21,091)

One year outcome	Exposure Group	Number of Patients	Number of Events	Follow Up Time (Days)			Unadjusted Incidence Rate (per 100 person-years)	Unadjusted Hazard Ratio (95%CI)	p	Adjusted Hazard Ratio (95%CI)	p
				Mean	SD	Median					
All-cause hospitalization [Any admission between t +1 and t+365 in Inpatient Admissions file]	CKD	1,593	680 (42.7%)	222.1	140.9	365	70.2				
	No CKD	19,498	5,292 (27.1%)	264.6	132.2	365	37.5	1.79 (1.65–1.94)	<0.001	1.19 (1.09–1.31)	<0.001
Atrial fibrillation hospitalization [ICD-9 code 427.31 associated with admission between t+1 and t+365 in Inpatient Admissions file]	CKD	1,593	208 (13.1%)	283.4	120.6	365	16.8				
	No CKD	19,498	2,409 (12.4%)	297.1	113.9	365	15.2	1.09 (0.95–1.26)	0.21	1.02 (0.87–1.20)	0.79
Cardioversion [CPT-4 codes 9962, 9961, 92960, or 92961 associated with an admission between t+1 and t+365 in Inpatient Admissions file OR CPT-4 codes 92960 or 92961 in the primary procedure position for an encounter in the Outpatient Services file]	CKD	1,593	343 (21.5%)	259.2	135.2	365	30.3				
	No CKD	19,498	3,910 (20.1%)	274.1	131.0	365	26.7	1.12 (0.99–1.24)	0.07	0.99 (0.87–1.12)	0.87
Repeat ablation for atrial fibrillation [ICD-9 code 427.31 and CPT-4 codes 37.34 associated with an admission between t+1 and t+365 in Inpatient Admissions file OR ICD-9 code 427.31 and CPT-4 93651 in the primary procedure position for an encounter in the Outpatient Services file]	CKD	1,593	184 (11.6%)	289.4	114.6	365	14.6				
	No CKD	19,498	2,816 (14.4%)	296.2	111.7	365	17.8	0.82 (0.70–0.95)	0.008	0.89 (0.76–1.06)	0.18

Note: Multivariable models were adjusted for age, sex, Charlson Comorbidity Index score, HF, hypertension, diabetes, stroke/TIA, prior MI, anemia, PAD or vascular disease, COPD, sleep apnea, year of ablation, insurance plan, and receipt of concomitant drug therapies.

Table 4

Secondary outcomes at one year after index ablation (N=21,091)

Cause of inpatient admission at one year	Exposure Group	Number of Patients	Number of Events	Follow Up Time (Days)			Unadjusted Incidence Rate (per 100 person-years)	Unadjusted Hazard Ratio (95%CI)	p	Adjusted Hazard Ratio (95%CI)	p
				Mean	SD	Median					
Myocardial infarction or unstable angina [ICD-9 codes: 410.x, 411.x, 412, 413, 413.0, 413.1, 413.9, 414.x, 429.7x, v17.3, v81.01]	CKD	1,593	30 (1.9%)	308.8	101.6	365	2.22				
	No CKD	19,498	186 (0.95%)	322.1	90.9	365	1.08	2.06 (1.40–3.02)	<0.001	0.99 (0.62–1.57)	0.95
Heart failure [ICD-9 codes: 398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.0, 425.1, 425.2, 425.3, 425.4, 425.5, 425.7, 425.8, 425.9, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9, 429.3]	CKD	1,593	127 (8.0%)	296.5	112.1	365	9.82				
	No CKD	19,498	281 (1.4%)	320.7	92.9	365	1.64	5.86 (4.75–7.22)	<0.001	2.26 (1.74–2.94)	<0.001
Supraventricular tachycardia [ICD-9 codes: 427.0, 427.61, 427.21]	CKD	1,593	9 (0.56%)	311.3	99.4	365	0.66				
	No CKD	19,498	50 (0.26%)	323.2	89.9	365	0.29	2.27 (1.12–4.61)	0.02	1.78 (0.76–4.13)	0.19
Ventricular arrhythmia [ICD-9 codes: 427.1, 427.2, 427.4, 427.41, 427.42, 427.6, 427.60, 427.69, 427.89]	CKD	1,593	26 (1.6%)	309.2	101.4	365	1.92				
	No CKD	19,498	164 (0.84%)	322.2	90.9	365	0.95	2.01 (1.33–3.04)	<0.001	1.25 (0.76–2.08)	0.38
Stroke or transient ischemic attack [ICD-9 codes: 434.0x, 434.1x, 434.9x, 435.9]	CKD	1,593	13 (0.82%)	311.0	99.8	365	0.96				
	No CKD	19,498	96 (0.49%)	322.9	90.3	365	0.56	1.71 (0.96–3.05)	0.07	0.95 (0.48–1.87)	0.88
Intracranial hemorrhage [ICD-9 codes: 430, 431, 432, 432.0, 432.1, 432.9]	CKD	1,593	6 (0.38%)	312.1	98.7	365	0.44				
	No CKD	19,498	31 (0.16%)	323.5	89.5	365	0.18	2.45 (1.02–5.87)	0.04	1.57 (0.55–4.45)	0.40

Cause of inpatient admission at one year	Exposure Group	Number of Patients	Number of Events	Follow Up Time (Days)			Unadjusted Incidence Rate (per 100 person-years)	Unadjusted Hazard Ratio (95%CI)	p	Adjusted Hazard Ratio (95%CI)	p
				Mean	SD	Median					
Syncope [ICD-9 codes: 780.2]	CKD	1,593	4 (0.25%)	311.9	99.0	365	0.29				
	No CKD	19,498	38 (0.19%)	323.5	89.6	365	0.22	1.32 (0.47–3.72)	0.59	0.72 (0.22–2.34)	0.58

Note: Multivariable models were adjusted for age, sex, Charlson Comorbidity Index score, HF, hypertension, diabetes, stroke/TIA, prior MI, anemia, PAD or vascular disease, COPD, sleep apnea, year of ablation, insurance plan, and receipt of concomitant drug therapies.