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ORIGINAL RESEARCH

Seasonal Variation of Atrial Fibrillation Admission and Quality of Care in the United States

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BACKGROUND: Currently, little is known regarding seasonal variation for atrial fibrillation (AF) in the United States and whether quality of care for AF varies between seasons.

METHODS AND RESULTS: The GWTG-AFib (Get With The Guidelines–AFib) registry was initiated by the American Heart Association to enhance national guideline adherence for treatment and management of AF. Our analyses included 61 291 patients who were admitted at 141 participating hospitals from 2014 to 2018 across the United States. Outcomes included numbers of AF admissions and quality-of-care measures (defect-free care, defined as a patient's receiving all eligible measures). For quality-of-care measures, generalized estimating equations accounting for within-site correlations were used to estimate odds ratios (ORs) with 95% CIs, adjusting patient and hospital characteristics. The proportion of AF admissions for each season was similar, with the highest percentage of AF admissions being observed in the fall (spring 25%, summer 25%, fall 27%, and winter 24%). Overall, AF admissions across seasons were similar, with no seasonal variation observed. No seasonal variation was observed for incident AF. There were no seasonal differences in care quality (multivariable adjusted ORs and 95% CIs were 0.93 (0.87–1.00) for winter, 1.09 (1.01–1.18) for summer, and 1.08 (0.97–1.20) for fall, compared with spring).

CONCLUSIONS: In a nationwide quality improvement registry, no seasonal variation was observed in hospital admissions for AF or quality of care for AF.

Key Words: atrial fibrillation ■ quality of care ■ season ■ United States

Worldwide, more than 34 million individuals have atrial fibrillation (AF), with ≈3 to 6 million Americans affected.[1] Its prevalence is projected to double over the next 25 years, with expected parallel increases in related morbidities (stroke, heart failure) and mortality.[1,2] While a multiplicity of risk factors that increase the likelihood of developing AF have been identified, the pathophysiological factors that contribute to the development of AF are not completely understood.[2] Furthermore, there is a limited understanding of what is driving the increasing prevalence of AF in North America. While some patient-specific factors have been explored, less is known about potential environmental influences and risk modifiers.

Some evidence suggests that AF has a seasonal variation, with a relatively higher incidence in the winter.[3–8] Seasonality in the incidence of AF could reflect variation in meteorological characteristics, environmental factors, background rates of respiratory and other infectious illnesses, and lifestyles factors. Prior work into the seasonal variation of AF was largely conducted in Israel[9] and European countries,[10] including Finland,[11] Poland,[10] and Denmark.[12] In contrast, in the United States, despite an increasing prevalence

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CLINICAL PERSPECTIVE

What Is New?

- Currently, little is known regarding seasonal variation for atrial fibrillation (AF) in the United States, and it is unknown if there is seasonal variation in the quality of care for AF.
- In a nationwide quality improvement registry, the GWTG-AFib (Get With The Guidelines–AFib) registry, we did not observe a seasonal variation in AF admission.
- Overall AF care quality was high, and there was no seasonal variation in quality of care for patients hospitalized with AF detected.

What Are the Clinical Implications?

- For hospitals participating the GWTG-AFib quality improvement program, overall AF care quality was high, with no seasonal variation in AF admission or care quality.
- Future investigations on AF seasonal trends and the association between season and outcome are needed.

Nonstandard Abbreviations and Acronyms

GWTG-AFib	Get With The Guidelines–AFib registry
PTTR	peak-to-trough ratio

and burden of AF, there is only 1 small study of 49 patients with AF reporting a higher risk of AF associated with low temperature.[13] There are no nationwide assessments of AF seasonality in the United States. Moreover, it is unknown if there is seasonal variation in the quality of care for AF.

The GWTG-AFib (Get With The Guidelines–AFib) registry was initiated by the American Heart Association in June 2013 as a national quality improvement initiative, aiming to enhance guideline adherence for treatment and management of AF.[14–16] Leveraging this unique and rich national data set, we examined seasonal variation in frequency of hospital admission of AF and the seasonal variation in the quality of care patients with AF received. We hypothesized that AF admission is higher in the winter and that there is no seasonal variation in AF quality of care in the United States.

METHODS

Data described in this article, code book, and analytic code will not be made publicly available. Information on the procedure to obtain and access data from the American Heart Association Get With The Guidelines–AFib registry is described at https://www.heart.org/en/professional/quality-improvement/get-with-the-guidelines/get-with-the-guidelines-afib under the information for Researchers.

Participating sites at the GWTG-AFib regularly[16] report patient-level data including demographic and clinical characteristics, detailed information on medical history, diagnosis, treatment, adherence to quality-of-care measures, hospital characteristics, and in-hospital outcomes. The GWTG-AFib registry has demonstrated high accuracy and reliability of abstracted data.[16]

All collected data was deidentified using a web-based patient management tool (Outcome, A Quintiles Company, Cambridge, MA) and analyzed at aggregated level at the data analysis center (Duke Clinical Research Institute, Durham, NC). Each participating hospital received either human research approval to enroll patients without individual consent under the Common Rule or a waiver of authorization and exemption from subsequent review by their institutional review board. IQVIA, Inc. serves as the data collection and coordination center. Duke Clinical Research Institute serves as the data analysis center and has an agreement to analyze the aggregate deidentified data for research purposes. This study was approved by the institutional review board of Duke University.

Study Population

All data in the GWTG-AFib registry included patients' admission information from January 3, 2014, to December 27, 2019, from a total of 167 participating hospitals across the United States. For 2019, data on 18 554 AF admissions were excluded from the current analyses because data collection was still ongoing by the time of the data analysis. We excluded patients who did not have a primary diagnosis of AF (n=9924), patients with missing AF as the primary diagnosis variable (n=4897), missing sex (n=166), or missing race (n=709); patients treated with comfort measures only (n=2374); patients who left against medical advice, discharge destination missing, or unable to determine (n=783); patients with admission data in 2013 because of small numbers of observations (n=491); and patients with admission year 2019 (n=18 554, data collection ongoing). Our final analytic sample consisted of 61 291 patients in the GWTG-AFib registry who were admitted at 141 hospital sites from January 1, 2014, to December 31, 2018 (Figure 1). The participating 141 hospitals were from all varying climate and geographic regions of the United States and were representative at a national level (34% from the Northeast, 15% from the Midwest, 35% from the South, and 16% from the West).

Seasonality

Our exposure of interest was seasonality. Climate data were obtained from the National Climatic Data Center of the National Oceanic and Atmospheric Administration. The GWTG-AFib sites were linked by latitude and longitude coordinates to the nearest weather stations as reported in the Historical Observing Metadata Repository. Seasons were defined as spring (March 20–June 20), summer (June 21–September 21), fall (September 22–December 20), and winter (December 21–March 19).

Outcomes Assessments

The primary outcome of interest was admission for AF at a national level. The number of AF admissions were calculated per month per year. Patients with a final clinical diagnosis of AF or atrial flutter (principal or secondary) who are at least 18 years of age were captured in the GWTG-AFib database on the basis of hospital inpatient or emergency department records (*International Classification of Diseases, Tenth Revision* [*ICD-10*] codes: I48.0, I48.1, I48.2, I48.3, I48.4, I48.91, I48.92).

Our secondary outcome of interest was adherence to quality-of-care measures for AF. The quality-of-care measures were defined as binary outcomes (yes, no) and were assessed using the following achievement metrics as well as defect-free measure. The achievement metrics included (1) angiotensin-converting enzyme inhibitors/angiotensin receptor blockers or angiotensin receptor/neprilysin inhibitors prescribed before discharge (when left ventricular ejection fraction [LVEF] is <40); (2) beta blocker prescribed before discharge (when LVEF is <40); (3) CHA_2DS_2-VASc risk score documented before discharge; (4) the Food and Drug Administration approved anticoagulation prescribed before discharge; (5) prothrombin time/international normalized ratio planned follow-up documented before discharge for warfarin treatment; and (6) statin at discharge in patients with AF and coronary artery disease, cerebrovascular accident/transient ischemic attack, peripheral vascular disease, or diabetes.[14] The defect-free measure was defined as yes or no, based on whether a patient with AF received all eligible achievement measures listed above.[14]

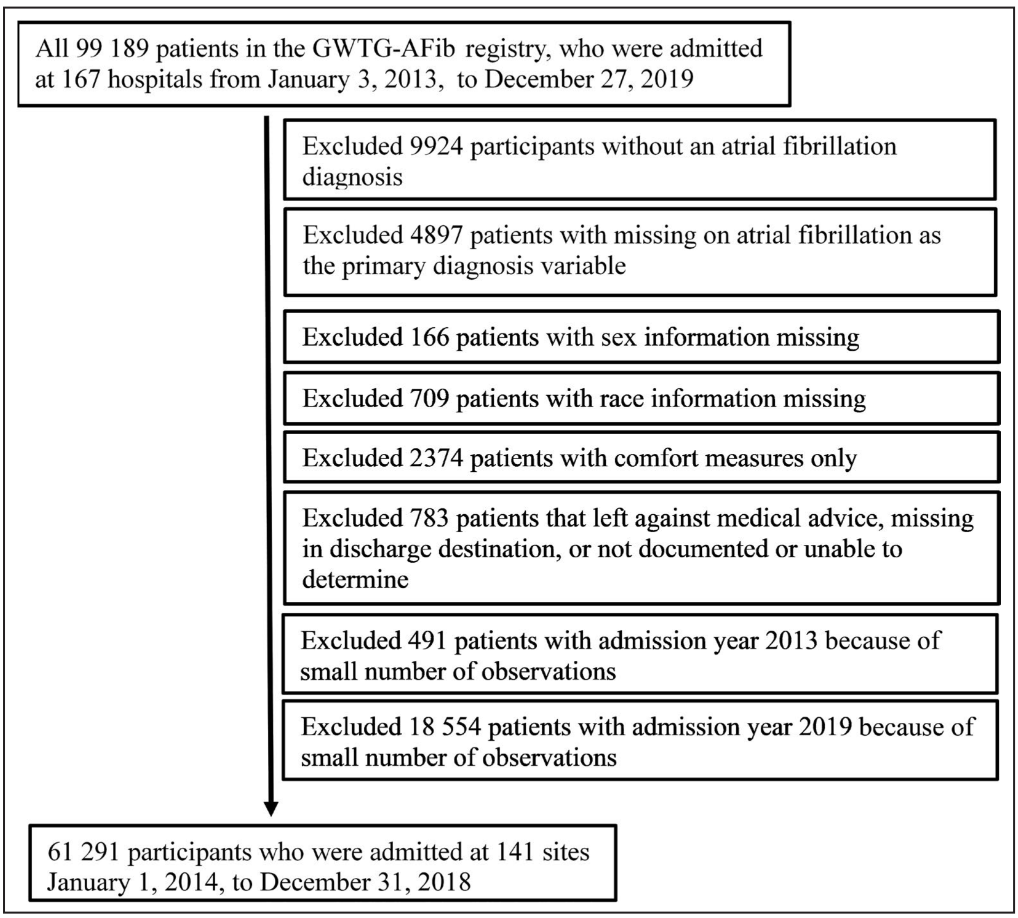

Figure 1. Flow diagram of the analytic sample.
GWTG-AFib indicates Get With The Guidelines-AFib registry.

Variables of Interest

Covariates associated with the occurrence of AF or quality of care were chosen a priori on the basis of the literature and were adjusted for patient- and hospital-level factors for the association of seasonality and quality-of-care measures. Patient-level characteristics include age, sex (male, female), race and ethnicity (White, Black, Other, Asian), insurance status (Medicare, Medicaid, Medicare private, private insurance, no insurance), smoking status, medical history, and comorbidities (congestive heart failure, history of diabetes, prior stroke/transient ischemic attack, history of vascular disease, dialysis, liver disease, obstructive sleep apnea, prior hemorrhage, prior myocardial infarction, prior percutaneous coronary intervention, thyroid disease, chronic obstructive pulmonary disease, estimated glomerular filtration rate <60 mg/dL, LVEF <40, labile international normalized ratio, prior major bleeding, prior cardioversion, prior ablation, and prior surgical maze procedure). Hospital-level characteristics include hospital type (academic versus teaching), number of beds (1–199, 200–299, 300–399, 400–499, 500+), geographic region (West, South, Midwest, Northeast), and annual AF case volume.

Statistical Analysis

Baseline characteristics, comorbidities, and hospital characteristics were described by season using percentages for categorical variables and medians with 25th and 75th percentiles for continuous variables. Differences in these characteristics were compared using Pearson's chi-squared test for categorical row variables and Kruskal-Wallis tests for continuous row variables.

For the association between seasonality and AF admission, we plotted numbers of AF admissions per each month per year. We used Pearson's chi-squared test to assess the difference in proportions of AF admissions per season. Additionally, we tested for differences in the number of AF admissions per season using a Poisson regression model with generalized estimating equations, with the number of admissions calculated at the site level. For subgroup analyses, we further examined seasonal variation in AF admissions across different age groups, race, sex, AF type (new onset, recurrent), and AF diagnosis (primary diagnosis, not primary diagnosis). We also examined seasonal variation overall and by subgroups using log-linear Poisson regression models fit to monthly AF admission data as a sensitivity analysis. The magnitude of seasonal variations is quantified by the peak-to-trough ratio (PTTR), which is interpreted as a relative risk, with the trough month as the reference level.[17] The model goodness of fit was also examined.

Logistic regression models with generalized estimating equations were used to assess the association between season and AF quality-of-care measures, accounting for within-site correlations. The model controlled for potential confounders chosen a priori. Age and annual AF and atrial flutter case volume were fit with restricted cubic splines. Minimum and maximum temperature were fit with linear splines. Finally, 7-day average precipitation was treated as linear and no splines were needed. For missing data, we used multiple imputation to impute covariates. Missingness in medical history variables were assumed to be "no." Patients ≥65 years old with missing insurance status was imputed to Medicare before using multiple imputation. Missingness in hospital-level variables and climate variables were not imputed. All variables had <2.5% missing except for 7-day average precipitation (5.8%), estimated glomerular filtration rate <60 (5.9%), LVEF <40 (10%), teaching hospital (10.5%), minimum temperature (11.2%), prior major bleeding (12.3%), and labile international normalized ratio (13.7%).

RESULTS

Study Cohort and Baseline Characteristics

The GWTG-AFib registry site reported that numbers of AF hospital admissions steadily increased from 2014 to 2018. The number of AF admission reported in 2014 was 4081 (7%), 9384 (15%) for 2015, 12 764 (21%) for 2016, 16 560 (27%) for 2017, and 18 502 (30%) for 2018. As shown in Table 1, there were no major clinical differences in GWTG-AFib patient characteristics by seasons.

Associations Between Seasonality and Admissions for AF

Overall, AF admission across seasons was similar with no seasonal variation observed: winter, 24%; spring, 25%; summer, 25%; and fall, 27%. Results were the same, with no seasonal variation observed for newly diagnosed and recurrent AF (Figure S1). Similarly, no seasonal variation in AF admissions was observed across different age groups, race, sex, and AF diagnosis (primary diagnosis, not as primary diagnosis). The numbers of AF admissions in the GWTG-AFib registry by month and per day were similar, with summer and winter seasons having slightly higher numbers of AF admissions. There was no difference between seasons (Figure 2; Table S1). The proportion of AF admissions for each season were similar, with the highest percentage of AF admissions being observed for the fall (spring, 25%; summer, 25%; fall, 27%; and winter, 24%; Table 2).

Table 1. Baseline Characteristics by Season

		Spring N=15 175	Summer N=15 307	Fall N=16 323	Winter N=14 486	*P* value
Demographics						
Age	Median (IQR)	71.0 (62.0–80.0)	71.0 (62.0–79.0)	71.0 (62.0–80.0)	72.0 (62.0–80.0)	<0.0001
Sex, n (%)	Male	7899 (52.1)	8031 (52.5)	8407 (51.5)	7388 (51.0)	0.06
	Female	7276 (47.9)	7276 (47.5)	7916 (48.5)	7098 (49.0)	
Race and ethnicity, n (%)	White	12 902 (85.0)	12 957 (84.6)	13 802 (84.6)	12 200 (84.2)	0.004
	Black	924 (6.1)	1005 (6.6)	1009 (6.2)	987 (6.8)	
	Hispanic	889 (5.9)	810 (5.3)	912 (5.6)	829 (5.7)	
	Asian	166 (1.1)	163 (1.1)	187 (1.1)	153 (1.1)	
Admission year, n (%)	2014	964 (6.4)	881 (5.8)	1324 (8.1)	912 (6.3)	<0.0001
	2015	2210 (14.6)	2416 (15.8)	2694 (16.5)	2064 (14.2)	
	2016	3132 (20.6)	3200 (20.9)	3472 (21.3)	2960 (20.4)	
	2017	4183 (27.6)	4195 (27.4)	4180 (25.6)	4002 (27.6)	
	2018	4686 (30.9)	4615 (30.1)	4653 (28.5)	4548 (31.4)	
Medical history, n (%)						
COPD	Yes	2524 (16.6)	2469 (16.2)	2679 (16.5)	2493 (17.2)	0.08
Coronary artery disease	Yes	4245 (28.0)	4166 (27.3)	4535 (27.9)	4060 (28.1)	0.1
Prior stroke or TIA	Yes	2056 (13.6)	2000 (13.1)	2120 (13.0)	1888 (13.1)	0.4
Diabetes	Yes	4194 (27.7)	4107 (26.9)	4486 (27.6)	3928 (27.2)	0.3
Heart failure	Yes	4030 (26.6)	4041 (26.4)	4298 (26.4)	3916 (27.1)	0.5
Hypertension	Yes	11 328 (74.7)	11 347 (74.2)	12 282 (75.4)	10 992 (76.0)	0.8
Other risk factors, n (%)						
CHA_2DS_2VASc score	Median (IQR)	4.0 (2.0–5.0)	4.0 (2.0–5.0)	4.0 (2.0–5.0)	4.0 (2.0–5.0)	<0.0001
ORBIT-AF score	Median (IQR)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	0.0002
LVEF <40	Yes	1979 (14.5)	2002 (14.6)	2099 (14.2)	1959 (15.1)	0.2
Hospital characteristics						
Academic/Teaching hospital, n (%)	Yes	11 137 (82.7)	11 487 (83.4)	12 225 (82.9)	10 588 (82.3)	0.1
Rural location, n (%)	Yes	1351 (10.4)	1301 (9.8)	1311 (9.2)	1236 (10.0)	0.008
Region, n (%)	Northeast	5200 (34.7)	5318 (35.1)	5642 (34.9)	4758 (33.2)	<0.0001
	Midwest	3058 (20.4)	3033 (20.0)	2901 (17.9)	2797 (19.5)	
	South	4933 (32.9)	4920 (32.5)	5579 (34.5)	4815 (33.6)	
	West	1807 (12.0)	1881 (12.4)	2066 (12.8)	1941 (13.6)	
Annual AF case volume	Median (IQR)	254 (174–497)	254 (175–497)	254 (175–497)	252 (174–406)	<0.0001
Performance measures, n (%)						
ACEI/ARB or ARNI prescribed before discharge (when LVEF <40)	Yes	1316 (73.0)	1315 (72.1)	1388 (73.1)	1288 (72.4)	0.9
Beta blocker prescribed before discharge (when LVEF <40)	Yes	1694 (94.8)	1726 (96.0)	1759 (95.0)	1700 (95.8)	0.2
CHA_2DS_2-VASc risk score documented before discharge	Yes	9304 (70.6)	9663 (72.8)	10 389 (73.5)	8346 (66.8)	<0.0001
FDA approved anticoagulation prescribed before discharge	Yes	10 224 (94.0)	10 405 (95.4)	11 119 (95.4)	9740 (93.9)	<0.0001
PT/INR planned follow-up documented before discharge for warfarin treatment	Yes	2759 (88.4)	2671 (88.5)	2801 (90.1)	2722 (89.2)	0.1

(*Continued*)

Table 1. (Continued)

		Spring N=15 175	Summer N=15 307	Fall N=16 323	Winter N=14 486	*P* value
Statin at discharge in patients with AF and CAD, CVA/TIA, PVD, or diabetes	Yes	5231 (78.1)	5138 (79.0)	5594 (79.5)	4978 (79.1)	0.2
Defect-free care measure (received all eligible measures)	Yes	8670 (61.6)	8994 (63.6)	9778 (64.5)	7984 (59.3)	<0.0001

P values are based on Pearson chi-squared tests for all categorical row variables and on Kruskal-Wallis tests for all continuous/ordinal row variables. ACEI/ARB indicates angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; AF, atrial fibrillation; ARNI, angiotensin receptor/neprilysin inhibitors; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; FDA, Food and Drug Administration; IQR, interquartile range; LVEF, left ventricular ejection fraction; ORBIT-AF, outcomes registry for better informed treatment of atrial fibrillation; PT/INR, prothrombin time/international normalized ratio; PVD, peripheral vascular disease; and TIA, transient ischemic attack.

We calculated PTTRs for AF admissions, with June designated as the trough month. In our analytic sample, November was identified as the peak month and June was the trough month. We observed a PTTR of 1.09 (95% CI, 1.05–1.13; Table S2; Figure S2). To determine the amplitude and phase and identify the peak month for the PTTR, formulas containing sine, cosine, and inverse tangent functions were used. These functions are periodic in nature, which lends themselves to the cyclical nature of admissions across a calendar year. When we examined the pattern of AF admissions across a calendar year, the assumption of the sine and cosine functions were not met since data did not follow a cyclical pattern. Our results and conclusion remained the same for sensitivity analyses when we plotted our data by weekly and calculated PTTR using incident AF cases only. Among incident AF cases only, January was identified as the peak month, and the PTTR was 1.13 (95% CI, 1.04–1.24).

Associations Between Seasonality and Quality-of-Care Measures for AF

When examining the percentage of patients whose treatment was adherent for all eligible measures (defect-free care), patients with AF admitted in the winter, summer, and fall seasons received similar care quality when compared with those admitted in the spring (Table 3). Patients with AF admitted in the winter were slightly less likely to receive defect-free care (odds ratio [OR], 0.93; 95% CI, 0.87–1.00; Table 3), and patients admitted in the summer were

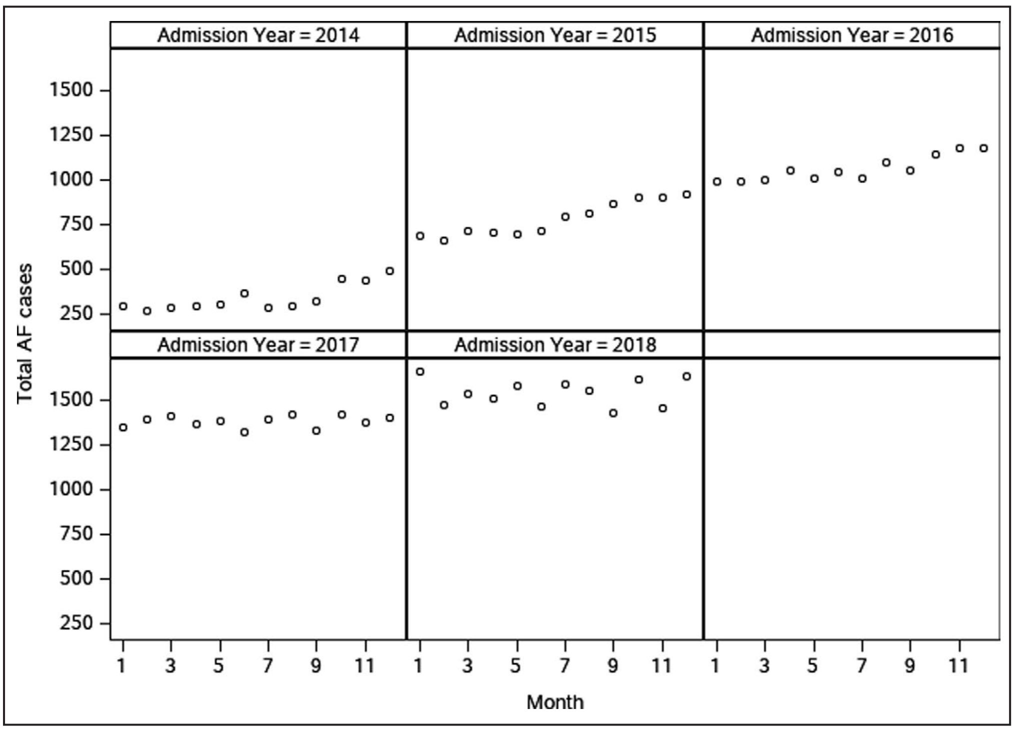

Figure 2. **Number of atrial fibrillation (AF) diagnoses per month per year.**

Table 2. Seasonal Variation of AF Admission

Variable	Spring		Summer		Fall		Winter		*P* value
AF cases in seasons	15 175	24.76	15 307	24.97	16 323	26.63	14 486	23.63	<0.0001*
AF cases not in season	46 116	75.24	45 984	75.03	44 968	73.37	46 805	76.37	
Total (overall N)	61 291	100.00	61 291	100.00	61 291	100.00	61 291	100.00	

*Pearson chi-squared test is used to test for differences in cases between the seasons. Additionally, we tested for differences in the number of AF admissions per season using a mixed-effects model assuming a Poisson distribution with the number of admissions calculated at the site level (*P*=0.0114). AF indicates atrial fibrillation.

slightly more likely to receive defect-free care (OR, 1.09; 95% CI, 1.01–1.18). A similar trend is seen for winter and summer admissions for the quality-of-care measure, CHA_2DS_2-VASc risk score documented before discharge, and beta blocker prescribed before discharge (when LVEF is <40) compared with spring admissions.

DISCUSSION

In GWTG-AFib, a large national quality improvement registry, we did not observe any seasonal variation in either hospital admission for AF or adherence to quality-of-care measures for AF.

Associations Between Seasons and Admissions for AF

Several thrombotic conditions, such as ischemic stroke[18,19] and acute myocardial infarction,[20–23] exhibit seasonal variation, with higher frequency of these events in the winter. These prior associations have led to the hypothesis that meteorological conditions have an impact on physiologic function and may serve as a trigger or effect modifier for the onset of AF. There are several potential hypotheses for how cardiovascular disease could be exacerbated in the winter. Low temperature or sudden temperature decrease may activate central angiotensin or hypothalamic receptors for mineralocorticoids; increase sympathetic function; and

Table 3. Association of Seasonality and AF Quality-of-Care Measures

Outcome	N	Variable	Unadjusted odds ratio (95% CI)	Adjusted* odds ratio (95% CI)
ACEI/ARB or ARNI prescribed before discharge (when LVEF<40)	5839	Summer	1.00 (0.81–1.24)	0.97 (0.79–1.19)
		Fall	1.04 (0.86–1.24)	1.02 (0.85–1.22)
		Winter	0.99 (0.83–1.17)	0.94 (0.79–1.11)
Beta blocker prescribed before discharge (when LVEF<40)	5799	Summer	1.49 (1.10–2.03)	1.49 (1.05–2.11)
		Fall	0.98 (0.78–1.24)	0.98 (0.76–1.27)
		Winter	1.42 (1.06–1.90)	1.39 (0.99–1.94)
CHA_2DS_2-VASc risk score documented before discharge	42 939	Summer	1.10 (1.01–1.19)	1.11 (1.01–1.22)
		Fall	1.06 (0.94–1.19)	1.06 (0.93–1.22)
		Winter	0.89 (0.83–0.94)	0.88 (0.82–0.94)
FDA-approved anticoagulation prescribed before discharge	35 647	Summer	1.23 (1.09–1.38)	1.28 (1.10–1.50)
		Fall	1.15 (1.04–1.27)	1.19 (1.03–1.38)
		Winter	0.96 (0.84–1.10)	0.95 (0.81–1.13)
PT/INR planned follow-up documented before discharge for warfarin treatment	10 097	Summer	1.07 (0.92–1.24)	1.07 (0.91–1.25)
		Fall	1.07 (0.94–1.23)	1.08 (0.95–1.24)
		Winter	1.10 (0.96–1.26)	1.11 (0.96–1.28)
Statin at discharge in patients with AF and CAD, CVA/TIA, PVD, or diabetes	21 391	Summer	1.06 (0.97–1.16)	1.07 (0.97–1.18)
		Fall	1.07 (0.97–1.17)	1.07 (0.97–1.18)
		Winter	1.05 (0.96–1.14)	1.06 (0.97–1.16)
Defect-free care measure (received all eligible measures)	45 963	Summer	1.09 (1.01–1.18)	1.09 (1.01–1.18)
		Fall	1.07 (0.97–1.19)	1.08 (0.97–1.20)
		Winter	0.94 (0.88–1.00)	0.93 (0.87–1.00)

Seasons reference group – spring. ACEI/ARB indicates angiotensin-converting enzyme inhibitors/angiotensin receptor blockers; ARNI, angiotensin receptor/neprilysin inhibitor; CAD, coronary artery disease; CVA, cerebrovascular accident; FDA, Food and Drug Administration; LVEF, left ventricular ejection fraction; PT/INR, prothrombin time/international normalized ratio; PVD, peripheral vascular disease; and TIA, transient ischemic attack.

*Adjusted for patient and hospital characteristics.

induce elevations of endothelin 1, renin, and angiotensin II plasmatic levels.[4,5,24,25] "Cold-induced hypertension" could increase intra-atrial pressure, leading to atrial enlargement and increased risk of AF.[4,5,24,25]

Prior investigations into seasonal variation in AF were predominantly from European countries and were reported among the general population and among patients with stroke.[26] Studies from Finland,[11] Denmark,[17] Poland,[10] and Israel[9] reported a seasonal variation of AF, with the highest risk in the winter. A study from Italy reported negative correlation between AF and temperature.[27] Previous evidence from North America has been limited. Only 1 small study of 49 patients with AF from a single US center was conducted[13] and reported a higher risk of AF associated with low temperature. To the best of our knowledge, this is the first study to examine the association between seasonality and admissions for AF across all geographic regions of the United States as well as across different age, sex, and racial groups. Our study provides evidence that there is no seasonal variation in AF risk in the United States, and these results were consistent among incident AF and recurrent AF, as well as across different age, sex, race, and other important subgroups.

Associations Between Seasonality and Quality of Care for AF

A recent study from Denmark and New Zealand reported a winter peak in incidence of stroke in patients with AF,[12] suggesting that there are opportunities to optimize treatment of AF and prevention of stroke, particularly in the winter season. In our study, we found that quality of care for AF was generally high and similar across all 4 seasons. We did not observe an association between seasonality and quality of care. There is a possibility that patients with AF admitted in the winter may receive lower care quality compared with other seasons. However, the potential explanations for this observed phenomenon are unclear, and this finding needs to be explored in future studies. By design, the GWTG-AFib registry was a voluntary quality improvement program. Thus, our study may have included higher-performing hospitals and potentially lead to a best-case scenario. Our analytical data were collected by medical chart review. It is unclear whether the accuracy and completeness of data documentation and abstraction varies depends on the time of the year, which might lead to biases attributable to differential accuracy of coding.[28] Future studies are needed to replicate this finding and to examine whether there is a winter peak in stroke among patients with AF in the United States.

Our study has several strengths. Our study was able to distinguish between incidence and prevalent AF cases and examined seasonal variation between several clinically important and vulnerable subgroups. Leveraging the rich data resources in the GWTG-AFib registry, we were able to examine this relation at a national level, with a large sample size across different geographic regions in the United States.

Our study is limited by not being able to directly compare occurrence of AF across ranges of meteorological factors, such as low temperature, sudden drop in temperature, atmospheric pressure, relative humidity, and so on. The GWTG-AFib database is a national initiative with hospitals volunteering participation, with participating hospitals across geographic regions in the United States. However, our data did not fully represent the AF population in the United States and thus limit the generalizability of our findings. Hospitals participating in the GWTG-AFib registry are mostly academic and urban. This is a limitation of the analysis, and the conclusions may not reflect the seasonal trends and the association between season and quality of care for nonacademic and rural hospitals. We have data only on AFIadmission, and true AF incidence could not be determined. We assessed difference in frequency of AF admission across seasons. The total numbers of AF cases were increasing over the year because the GWTG-AFib registry was expanding and enrolling new hospital sites and accruing new patients over time. Because of the nature of the data collection process, we could not include recent AF data in 2019 in the analysis since not all data have been collected. Despite the fact that we have accounted for characteristics at patient and hospital levels and adjusted for various meteorological variables, our study is still subject to unmeasured confounding (eg, infections, influenza, air pollution levels).

In conclusion, in the GWTG-AFib registry, we did not observe a seasonal variation in AF admission. Overall, AF care quality was high and there was no seasonal variation in quality of care for patients hospitalized with AF.

ARTICLE INFORMATION

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Supplemental Material

Tables S1–S2
Figures S1–S2

REFERENCES

1. Chugh SS, Havmoeller R, Narayanan K, Singh D, Rienstra M, Benjamin EJ, Gillum RF, Kim Y-H, McAnulty JH, Zheng Z-J, et al. Worldwide epidemiology of atrial fibrillation: a global burden of disease 2010 study. *Circulation*. 2014;129:837–847. doi: 10.1161/circulationaha.113.005119
2. Benjamin EJ, Chen P-S, Bild DE, Mascette AM, Albert CM, Alonso A, Calkins H, Connolly SJ, Curtis AB, Darbar D, et al. Prevention of atrial fibrillation: report from a National Heart, Lung, and Blood Institute workshop. *Circulation*. 2009;119:606–618. doi: 10.1161/CIRCULATIONAHA.108.825380
3. Kountouris E, Korantzopoulos P, Dimitroula V, Bartzokas A, Siogas K. Is there a seasonal variation in hospital admissions for acute-onset atrial fibrillation? *Cardiol*. 2005;103:79–80. doi: 10.1159/000082052
4. Bhatnagar A. Environmental determinants of cardiovascular disease. *Circ Res*. 2017;121:162–180. doi: 10.1161/circresaha.117.306458
5. Stewart S, Keates AK, Redfern A, McMurray JJV. Seasonal variations in cardiovascular disease. *Nat Rev Cardiol*. 2017;14:654–664. doi: 10.1038/nrcardio.2017.76
6. Ahn J, Uhm T, Han J, Won K-M, Choe JC, Shin JY, Park JS, Lee HW, Oh J-H, Choi JH, et al. Meteorological factors and air pollutants contributing to seasonal variation of acute exacerbation of atrial fibrillation: a population-based study. *J Occup Environ Med*. 2018;60:1082–1086. doi: 10.1097/jom.0000000000001449
7. Oliveira Junior NA. The cold season begins in the tropics. Cryoablation for atrial fibrillation in Brazil. *Arq Bras Cardiol*. 2020;115:536–537. doi: 10.36660/abc.20200658
8. Vencloviene J, Babarskiene RM, Dobozinskas P, Dedele A, Lopatiene K, Ragaisyte N. The short-term associations of weather and air pollution with emergency ambulance calls for paroxysmal atrial fibrillation. *Environ Sci Pollut Res Int*. 2017;24:15031–15043. doi: 10.1007/s11356-017-9138-7
9. Viskin S, Golovner M, Malov N, Fish R, Alroy I, Vila Y, Laniado S, Kaplinsky E, Roth A. Circadian variation of symptomatic paroxysmal atrial fibrillation. Data from almost 10 000 episodes. *Eur Heart J*. 1999;20:1429–1434. doi: 10.1053/euhj.1999.1632
10. Głuszak A, Kocoń S, Zuk K, Aljabali P, Gluza A, Siwek K. Episodes of atrial fibrillation and meteorological conditions. *Kardiol Pol*. 2008;66:958–963; discussion 64–5.
11. Kupari M, Koskinen P. Seasonal variation in occurrence of acute atrial fibrillation and relation to air temperature and sale of alcohol. *Am J Cardiol*. 1990;66:1519–1520. doi: 10.1016/0002-9149(90)90549-g
12. Christensen AL, Rasmussen LH, Baker MG, Lip GY, Dethlefsen C, Larsen TB. Seasonality, incidence and prognosis in atrial fibrillation and stroke in Denmark and New Zealand. *BMJ Open*. 2012;2:e001210. doi: 10.1136/bmjopen-2012-001210
13. Nguyen JL, Link MS, Luttmann-Gibson H, Laden F, Schwartz J, Wessler BS, Mittleman MA, Gold DR, Dockery DW. Drier air, lower temperatures, and triggering of paroxysmal atrial fibrillation. *Epidemiol*. 2015;26:374–380. doi: 10.1097/EDE.0000000000000284
14. Piccini JP, Xu H, Cox M, Matsouaka RA, Fonarow GC, Butler J, Curtis AB, Desai N, Fang M, McCabe PJ, et al. Adherence to guideline-directed stroke prevention therapy for atrial fibrillation is achievable. *Circulation*. 2019;139:1497–1506. doi: 10.1161/circulationaha.118.035909
15. Vallakati A, Lewis WR. Underuse of anticoagulation in patients with atrial fibrillation. *Postgrad Med*. 2016;128:191–200. doi: 10.1080/00325481.2016.1132939
16. Lewis WR, Piccini JP, Turakhia MP, Curtis AB, Fang M, Suter RE, Page RL 2nd, Fonarow GC. Get With The Guidelines AFib: novel quality improvement registry for hospitalized patients with atrial fibrillation. *Circ Cardiovasc Qual Outcomes*. 2014;7:770–777. doi: 10.1161/circoutcomes.114.001263
17. Frost L, Johnsen SP, Pedersen L, Husted S, Engholm G, Sørensen HT, Rothman KJ. Seasonal variation in hospital discharge diagnosis of atrial fibrillation: a population-based study. *Epidemiol*. 2002;13:211–215. doi: 10.1097/00001648-200203000-00017
18. Huang HK, Chang WC, Hsu JY, Wang JH, Liu PS, Lin SM, Loh CH. Holiday season and weekend effects on stroke mortality: a nationwide cohort study controlling for stroke severity. *J Am Heart Assoc*. 2019;8:e011888. doi: 10.1161/jaha.118.011888
19. Chu SY, Cox M, Fonarow GC, Smith EE, Schwamm L, Bhatt DL, Matsouaka RA, Xian Y, Sheth KN. Temperature and precipitation associate with ischemic stroke outcomes in the United States. *J Am Heart Assoc*. 2018;7:e010020. doi: 10.1161/jaha.118.010020
20. Moholdt T, Afoakwah C, Scuffham P, McDonald CF, Burrell LM, Stewart S. Excess mortality at Christmas due to cardiovascular disease in the HUNT study prospective population-based cohort in Norway. *BMC Public Health*. 2021;21:549. doi: 10.1186/s12889-021-10503-7

21. Chu ML, Shih CY, Hsieh TC, Chen HL, Lee CW, Hsieh JC. Acute myocardial infarction hospitalizations between cold and hot seasons in an island across tropical and subtropical climate zones—a population-based study. *Int J Environ Res Public Health*. 2019;16:2769. doi: 10.3390/ijerph16152769
22. Harvey NC, Lorentzon M, Kanis JA, McCloskey E, Johansson H. Incidence of myocardial infarction and associated mortality varies by latitude and season: findings from a Swedish registry study. *J Public Health*. 2020;42:e440–e448. doi: 10.1093/pubmed/fdz131
23. Park IH, Jang WJ, Cho HK, Oh JH, Chun WJ, Park YH, Lee M, Song YB, Hahn J-Y, Choi S-H, et al. Season and myocardial injury in patients with ST-segment elevation myocardial infarction: a cardiac magnetic resonance imaging study. *PLoS One*. 2019;14:e0211807. doi: 10.1371/journal.pone.0211807
24. Bruno RM, Di Pilla M, Ancona C, Sørensen M, Gesi M, Taddei S, Munzel T, Virdis A. Environmental factors and hypertension. *Curr Pharm Des*. 2017;23:3239–3246. doi: 10.2174/1381612823666170321162233
25. Schulz PS, Zimmerman L, Johansson P. Seasonal work and cardiovascular risk factors in farmers. *J Cardiovasc Nurs*. 2018;33:E35–E39. doi: 10.1097/jcn.0000000000000490
26. Fustinoni O, Saposnik G, Esnaola y Rojas MM, Lakkis SG, Sposato LA. Higher frequency of atrial fibrillation linked to colder seasons and air temperature on the day of ischemic stroke onset. *J Stroke Cerebrovasc Dis*. 2013;22:476–481. doi: 10.1016/j.jstrokecerebrovasdis.2013.03.009
27. Comelli I, Ferro J, Lippi G, Comelli D, Sartori E, Cervellin G. Incidence of acute-onset atrial fibrillation correlates with air temperature. Results of a nine-year survey. *J Epidemiol Glob Health*. 2014;4:151–157. doi: 10.1016/j.jegh.2013.12.003
28. Li L, Rothwell PM. Biases in detection of apparent "weekend effect" on outcome with administrative coding data: population based study of stroke. *BMJ*. 2016;353:i2648. doi: 10.1136/bmj.i2648

SUPPLEMENTAL MATERIAL

Table S1. Number of atrial fibrillation (AFIB) admission in the GWTG-AFIB registry by month, per day.

	Total (2014-2018)		**Annually**	
	Per Month	**Per Day**	**Per Month**	**Per Day**
January	4983	161	997	33
February	4784	170	957	34
March	4952	160	991	32
April	4931	165	987	33
May	4974	161	995	33
June	4904	164	981	33
July	5073	164	1015	33
August	5185	168	1037	34
September	4994	167	999	34
October	5525	179	1105	36
November	5352	179	1071	36
December	5634	182	1127	37

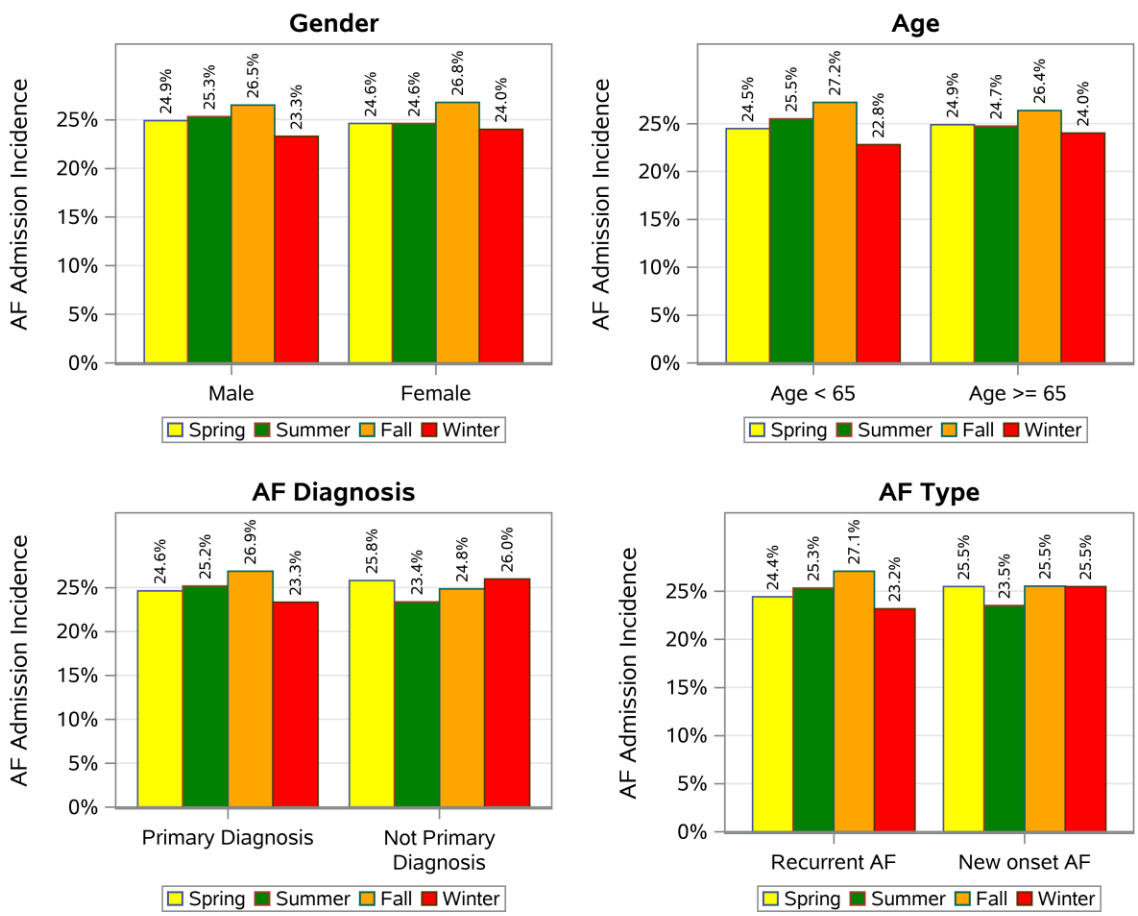
Table S2. Peak to trough ratios overall and by subgroups for atrial fibrillation (AFIB) admissions.

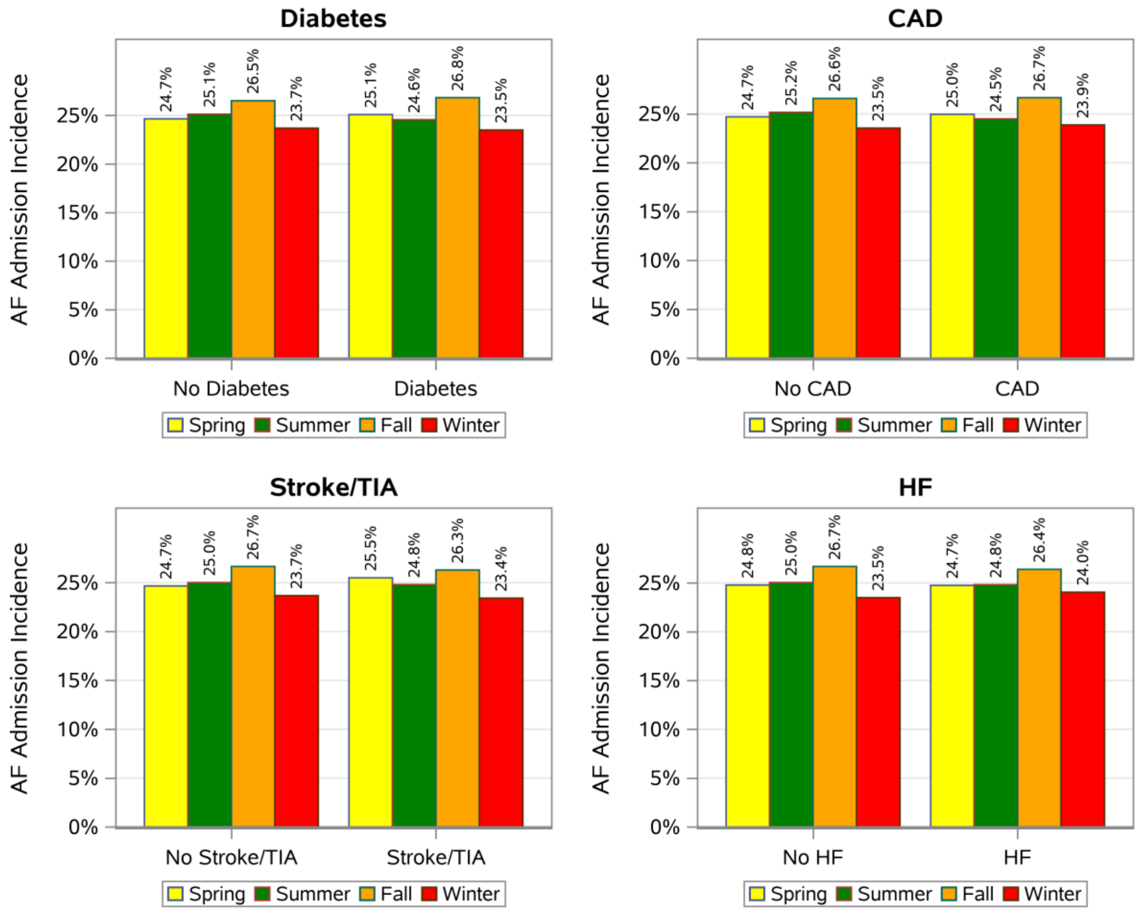
	Relative Risk (95% CI)	Peak Month	P-value
Overall	1.09 (1.05-1.13)	November	<.0001
Stratified analyses		.	.
Sex		.	.
Male	1.05 (0.99-1.10)	November	0.10
Female	1.14 (1.08-1.21)	November	<.0001
Age, years		.	.
< 65	1.15 (1.08-1.23)	October	<.0001
≥ 65	1.08 (1.03-1.13)	November	0.001
Race/Ethnicity		.	.
White	1.09 (1.05-1.14)	November	<.0001
Black or African-American	1.04 (0.89-1.22)	November	0.59
Hispanic	1.07 (0.90-1.26)	February	0.46
Asian	1.15 (0.81-1.61)	November	0.44
Other	1.23 (0.95-1.57)	November	0.11
AFIB admission diagnosis		.	.
Primary Diagnosis	1.11 (1.07-1.16)	November	<.0001
Primary Non-Diagnosis	1.14 (1.02-1.28)	March	0.01
AFIB type		.	.
New-onset/incident AFIB	1.13 (1.04-1.24)	January	0.004

	Relative Risk (95% CI)	Peak Month	P-value
Recurrent AFIB	1.10 (1.05-1.15)	November	<.0001
Diabetes		.	.
Yes	1.07 (1.00-1.15)	November	0.06
No	1.10 (1.05-1.15)	November	<.0001
Coronary Artery Disease		.	.
Yes	1.13 (1.05-1.22)	December	0.0008
No	1.09 (1.04-1.14)	November	0.0002
Stroke		.	.
Yes	1.07 (0.96-1.19)	November	0.20
No	1.09 (1.05-1.14)	November	<.0001
Heart Failure		.	.
Yes	1.02 (0.95-1.10)	November	0.60
No	1.12 (1.07-1.17)	November	<.0001

* Trough month was June for all analyses

Figure S1. Incidence of atrial fibrillation (AFIB) admissions by seasons stratified by subgroups.




Diabetes
AF Admission Incidence
0%
5%
10%
15%
20%
25%
24.7%
25.1%
26.5%
23.7%
25.1%
24.6%
26.8%
23.5%
No Diabetes
Diabetes
Spring Summer Fall Winter
CAD
AF Admission Incidence
0%
5%
10%
15%
20%
25%
24.7%
25.2%
26.6%
23.5%
25.0%
24.5%
26.7%
23.9%
No CAD
CAD
Spring Summer Fall Winter
Stroke/TIA
AF Admission Incidence
0%
5%
10%
15%
20%
25%
24.7%
25.0%
26.7%
23.7%
25.5%
24.8%
26.3%
23.4%
No Stroke/TIA
Stroke/TIA
Spring Summer Fall Winter
HF
AF Admission Incidence
0%
5%
10%
15%
20%
25%
24.8%
25.0%
26.7%
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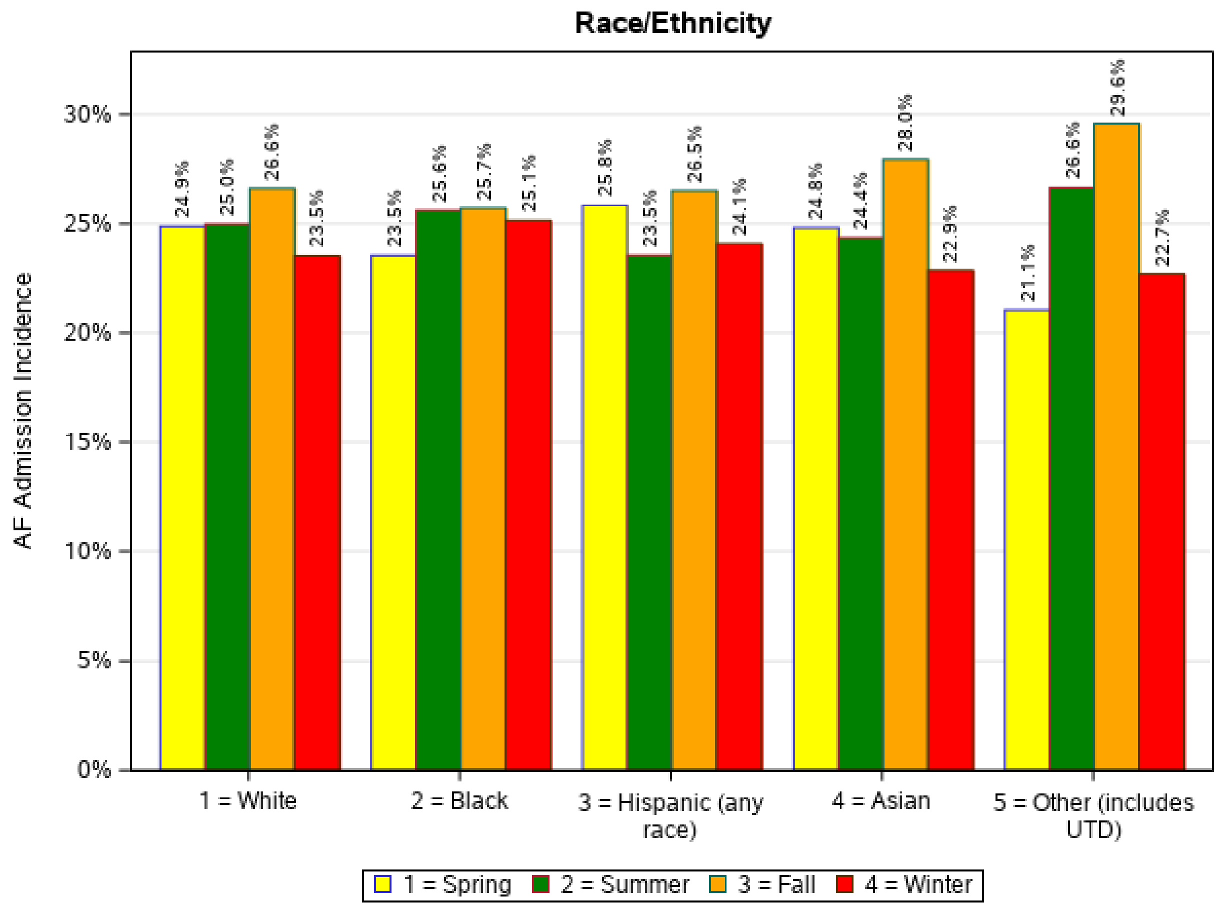
24.7%
24.8%
26.4%
24.0%
No HF
HF
Spring Summer Fall Winter



AF-atrial fibrillation
CAD-Coronary artery disease
TIA -transient ischemic attack
HF-heart failure

Figure S2. Daily number of atrial fibrillation (AFIB) admissions, mean daily maximum temperature in degrees (Celsius) by month of admission.