ORIGINAL RESEARCH

Emergency Department Visits for Atrial Fibrillation in the United States: Trends in Admission Rates and Economic Burden From 2007 to 2014

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***Background*—**Atrial fibrillation (AF) is an increasingly prevalent public health problem and one of the most common causes of emergency department (ED) visits. We aimed to investigate the trends in ED visits and hospital admissions for AF.

***Methods and Results*—**This is a repeated cross-sectional analysis of ED visit-level data from the Nationwide Emergency Department Sample for 2007 to 2014. We identified adults who visited EDs in the United States, with a principal diagnosis of AF. A sample of 864 759 ED visits for AF, representing a weighted total of 3 886 520 ED visits, were analyzed. The annual ED visits for AF increased by 30.7% from 411 406 in 2007 (95% confidence interval, 389 819–432 993) to 537 801 (95% confidence interval, 506 747–568 855) in 2014. Patient demographics remained consistent, with an average age of 69 to 70 years and slight female predominance (51%–53%) throughout the study period. Hospital admission rates were stable at ≈70% between 2007 and 2010, after which they gradually declined to 62% in 2014 (P_{trend}=0.017). Despite the decline in hospital admission rates, AF hospitalizations increased from 288 225 in 2007 to 333 570 in 2014 because of the increase in total annual ED visits during the study. The adjusted annual charges for admitted AF patients increased by 37% from $7.39 billion in 2007 to $10.1 billion in 2014.

***Conclusions*—**Annual ED visits and hospital admissions for AF increased significantly between 2007 and 2014, despite a reduction in admission rates. These data emphasize the need for widespread implementation of effective strategies aimed at improving the management of patients with AF to reduce hospital admissions and the economic burden of AF. **(*J Am Heart Assoc*. 2018;7: e009024. DOI: 10.1161/JAHA.118.009024.)**

Key Words: atrial fibrillation • economic burden • emergency department visits • hospitalization

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in adults, with a reported worldwide prevalence of 33.5 million in 2010.[1] The incidence and prevalence of AF continue to increase, driven by the aging of the world population and upsurge in risk factors, such as hypertension, heart failure, obesity, and sleep apnea.[2]

AF is associated with significant morbidity,[3–5] increased mortality,[6] and increasing healthcare costs, making it a major public health challenge and socioeconomic burden.[7] Hospitalizations related to AF increased >2.4-fold from 1985 to 1999,[8] and by an additional 23% in the past decade,[9] contributing to the increasing costs associated with AF over the years. The annual cost of AF treatment was estimated to be $6.65 billion in 2005,[7] and later estimates were even higher.[10] Intervention programs at the emergency department (ED) level have been investigated and successfully implemented in some academic centers in recent years to reduce the hospitalization rates for AF and their associated costs.[11–15]

Examination of ED visits and hospital admissions in the United States up until 2010 reveals a relatively stable high rate of hospitalizations for AF of ≈69% to 70%.[16] The impact of changes in the US healthcare system and the management of AF in recent years is still unknown. The aim of this study

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An accompanying Data S1 is available at http://jaha.ahajournals.org/content/7/15/e009024/DC1/embed/inline-supplementary-material-1.pdf

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Clinical Perspective

What Is New?

- Contemporary data show that the annual number of emergency department visits for atrial fibrillation (AF) have continued to increase in recent years.
- Despite a decline in hospital admission rates from ≈70% in 2010 to 62% in 2014, the annual admissions volume has continued to increase in recent years because of the increase in the volume of emergency department visits for AF.
- These trends, together with a substantial increase in the median hospital charge per patient over the 8 years of this study, have contributed to an alarming growth in the economic burden associated with AF in the United States.

What Are the Clinical Implications?

- These data underscore the need for widespread implementation of proven intervention strategies aimed at improving the management of patients with AF, reducing the volume of emergency department visits, and substantially reducing admission rates for AF in the United States.

was to investigate current trends in ED visits and hospital admissions for AF in the most recent years for which nationwide data are available.

Methods

The national database data used for this study, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure because of restrictions on the sharing of data in the Healthcare Cost and Utilization Project Data Use Agreement. The Nationwide Emergency Department Sample (NEDS) database is publicly available for purchase, and the transparent and detailed methods that we have described make it possible for anyone who wants to do so to replicate this study and reproduce our results.

This study is a repeated cross-sectional analysis of US ED visits using data from the NEDS, the Healthcare Cost and Utilization Project, and the Agency for Healthcare Research and Quality. We used the Strengthening the Reporting of Observational Studies in Epidemiology Statement checklist and recommendations to improve the description of the findings in this study.[17]

Data Source

The NEDS is the largest collection of all-payer ED data in the United States. The data set contains the discharge data of ≈30 million unweighted ED visits for each year of the database. These data are obtained from hospital-based ED visits to >900 hospitals across >30 states, representing an ≈20% stratified sample of all ED visits in US hospitals for each year. National estimates can be calculated using the sampling weights that are provided by the Healthcare Cost and Utilization Project. The database provides deidentified billing record information for each visit and, thus, was deemed exempt from institutional review by the Human Research Committee at Massachusetts General Hospital (Boston, MA).

Study Population

International Classification of Diseases, Ninth Revision, Clinical Modification (*ICD-9-CM*) and *Current Procedural Terminology (CPT), Fourth Edition* are used for reporting diagnoses and procedures in the NEDS database. For each visit, the database provides a principal discharge diagnosis and a maximum of 14 additional diagnoses, in addition to a maximum of 15 procedures. We identified all adults ≥18 years of age who visited EDs between January 1, 2007, and December 31, 2014, and had a principal diagnosis of AF (*ICD-9 CM* code 427.31).

Study Variables and Outcomes

There are >100 clinical and nonclinical variables for each ED visit, including patient- and hospital-level factors: age, sex, median household income, diagnoses and ED procedures, expected payment source, disposition, hospital region, hospital teaching status, hospital ED volume, and total ED charges. Along with the database, an additional supplemental data set is provided with inpatient data (eg, inpatient procedures, length of stay, and total hospital charges) for ED visits that resulted in hospital admission. The database provides 2 variables for calculation of service charges. For events with ED-only services (ie, nonadmitted patients), a total charge for ED services is provided. For admitted patients, a variable containing the sum of both ED and inpatient service charges is provided. For the purpose of calculating the Elixhauser Comorbidity Index, an additional list of comorbidities was generated from the database from *ICD-9-CM* codes using the Agency for Healthcare Research and Quality Comorbidity Software.

The primary outcome of the study was to identify ED visits that resulted in hospital admission. We categorized patients as admitted if the disposition status was admission as an inpatient to the same hospital or transfer to a short-term hospital. To calculate the CHA_2DS_2-VASc (congestive heart failure, hypertension, age, diabetes mellitus, stroke, vascular disease, sex) score, we created dummy variables for individual elements of the score, then looked for the presence of each element by using the comorbidities from the Elixhauser comorbidity score when available, or measured them by using the relevant Clinical Classification Software and/or *ICD-9-CM* codes.

Statistical Analysis

Weight files provided by the Agency for Healthcare Research and Quality were used to reflect national estimates. The NEDS data are collected from nonrehabilitation US hospitals that participated in the American Heart Association Annual Survey Database. These hospitals are stratified on the basis of multiple factors: geographic region, urban-rural location, teaching status, trauma center status, and hospital ownership and control. National estimates were calculated using a well-validated weighting method provided by the Agency for Healthcare Research and Quality. For each hospital of each stratum in each calendar year, sample weights are calculated by dividing the total number of ED visits in that stratum by the total number of adjusted ED visits from the sampled hospital. A detailed description of the previously validated weighting method, along with the formula, is provided in Data S1. The χ^2 test and Wilcoxon rank sum test were used to compare categorical variables and continuous variables, respectively. Trends for continuous variables were tested using the nonparametric test for trend by Cuzick.[18] To compare trends of admission between all-cause ED visits and the AF ED subgroup, joinpoint regression models with age- and sex-standardized admission rates were used. Models were fitted with the permutation selection method and autocorrelation errors to calculate the average annual percentage change over time. For the purpose of economic trend analysis, hospital charges were adjusted for 2014 as the target year, by using the medical care component of the Consumer Price Index inflation calculator from the Bureau of Labor Statistics.

To account for hospital-level clustering of discharges, we generated a 2-level mixed-effects multivariable logistic regression model to identify independent predictors of admission. Congruent with the Healthcare Cost and Utilization Project NEDS design, hospital identification number was used as a random effect, with patient-level factors clustered within hospital-level factors. Candidate variables included patient-level characteristics, Elixhauser Comorbidity Index, hospital-level factors, and hospital volume. For all analyses, we used survey estimation in Stata/SE 14.1 (StataCorp LP, College Station, TX) to account for the complex survey design of the NEDS database. Joinpoint regression analysis was performed using the Joinpoint Regression Program, version 4.5.0.1 (National Cancer Institute, Bethesda, MD). $P<0.05$ was considered significant.

Results

From a total of 233 007 973 unweighted ED visits during the 2007 to 2014 period, a total of 864 759 unweighted ED visits for AF were included in the final analysis. After implementing the weighting method, this represented an estimated total of 3 886 520 (95% confidence interval, 3 736 118–4 036 922) nationwide ED visits with AF as the principal diagnosis between 2007 and 2014. The annual number of AF ED visits increased by 30.7% from 411 406 in 2007 (95% confidence interval, 389 819–432 993) to 537 801 (95% confidence interval, 506 747–568 855) in 2014 (P_{trend}=0.008).

Demographic Characteristics

Patient clinical characteristics are presented in Table 1. Trends in patient- and hospital-related parameters over the study period are shown in Table 2. Overall, 42.1% of patients visiting EDs during the study period with a primary diagnosis of AF were ≥75 years old, and 52.1% were women. The median (interquartile range) ages for all AF ED visits and for visits that resulted in admission from 2007 to 2014 were 71 (60–81) and 73 (62–82) years, respectively. The proportion of patients aged >75 years old decreased slightly by 3.5% from 2007 to 2014 (P_{trend}=0.017).

Comorbidities

The most common comorbidity in patients presenting to the ED for AF was hypertension (61.8%), followed by congestive heart failure (24.5%), diabetes mellitus (21%), and chronic kidney disease (10.2%). Over the study period, there was a significant increase in the prevalence of individual comorbidities, as well as the mean comorbidity index (P_{trend}=0.008). Between 2007 and 2014, 8.6% of all patients who presented to EDs with a principal diagnosis of AF were at low risk for thromboembolic events (CHA_2DS_2-VASc score, 0), whereas 78.2% were considered high risk (CHA_2DS_2-VASc score, ≥2). There was a significant trend for sicker patients presenting to the ED for AF over the years, with a 14.2% increase in hypertension, a 19.2% increase in diabetes mellitus, a 20.8% increase in heart failure, and a 61.9% increase in the prevalence of chronic kidney disease between 2007 and 2014 (Figure 1).

Crude Visit Volumes and Admission Rates

As shown in Figure 2, there was a significant increase in the annual volume of ED visits for AF during the study period (31.7% increase, P_{trend}=0.008). The crude admission rates for a primary diagnosis of AF were stable at ≈69% to 70% until 2011 and gradually declined to 62% in 2014 (11.4% decline, P_{trend}=0.017). Despite the decline in admission rates for AF, the annual AF hospitalization volume increased 16% over the study period from 288 225 in 2007 to 333 570 in 2014, because of a continual increase in total annual ED visits for AF. For comparison, all-cause ED visits increased by 12.7%, and the crude admission rates declined by 6.6%, during the 8-year study period (Figure 2).

Table 1. Baseline Patient Characteristics for AF-Related ED Visits in the United States From 2007 to 2014

Characteristics	Total	Admitted Patients	Discharged Patients	*P* Value
Nonweighted, n	864 759	586 339	278 420	. . .
Weighted, n	3 886 520	2 617 064	1 269 456	. . .
Age group, y, %				
≤74	57.93	54.42	65.18	<0.001
≥75	42.07	45.58	34.82	
Sex, %				
Male	47.89	46.34	51.08	<0.001
Female	52.11	53.66	48.92	
Payer, %				
Medicare	63.81	67.43	56.35	<0.001
Medicaid	4.58	4.89	3.93	
Private	25.3	21.66	32.82	
Self-pay	3.77	3.5	4.33	
Others	2.53	2.52	2.56	
Income status, percentile				
0–25	24.49	25.94	21.51	<0.001
26–50	27.14	27.15	27.12	
51–75	24.75	24.18	25.92	
76–100	23.61	23.73	25.44	
Comorbidities, %				
Hypertension	61.82	69.89	45.18	<0.001
Congestive heart failure	24.47	32.11	8.71	<0.001
Diabetes mellitus	20.98	24.5	13.73	<0.001
Valvular disease	13.8	18.16	4.81	<0.001
Chronic kidney disease	10.24	13.27	4	<0.001
Chronic pulmonary disease	20.53	25.98	9.3	<0.001
CHA_2DS_2-VASc score, %				
0	8.56	5.24	15.4	<0.001
1	13.29	10.45	19.14	
≥2	78.15	84.31	65.46	
Mean±SEM	3.10±0.01	3.47±0.01	2.34±0.01	
Elixhauser Comorbidity Index ≥3, %	61.61	75.99	31.97	<0.001
Hospital teaching status, %				
Metropolitan nonteaching	43.35	44.06	41.88	<0.001
Metropolitan teaching	38.99	39.94	37.03	
Nonmetropolitan	17.66	16	21.09	
Hospital region, %				
Northeast	19.3	20.89	16.03	<0.001
Midwest	24.18	23.44	25.7	
South	37.6	40.25	32.13	
West	18.92	15.41	26.15	

AF indicates atrial fibrillation; ED, emergency department.

Table 2. Demographic Trends in Baseline Characteristics of the Patient Population Arriving to EDs for AF Between 2007 and 2014

Variable	Total	2007	2008	2009	2010	2011	2012	2013	2014	*P* Value for Trend	Trend*
Nonweighted, n	864 759	89 056	101 211	102 979	105 862	110 519	118 838	115 502	120 792	. . .	. . .
Weighted, n	3 886 520	411 406	445 924	462 794	479 691	504 995	516 517	527 393	537 801	0.008	↑
Age group, y, %											
≤59	23.96	24.99	24.36	24.13	24.35	23.99	24.02	22.97	23.23	0.014	↓
60–74	33.97	32.36	32.74	33.36	33.52	34.19	34.2	35.08	35.63	0.008	↑
≥75	42.07	42.64	42.9	42.51	42.13	41.82	41.78	41.94	41.14	0.017	↓
Median (IQR)	71 (60–81)	72 (59–81)	72 (60–81)	71 (60–81)	71 (60–81)	71 (60–81)	71 (60–81)	71 (61–81)	71 (60–81)	···	···
Sex, %											
Male	47.89	47.62	47.52	47.38	47.76	47.64	48.12	48.25	48.59	0.02	↑
Female	52.11	52.38	52.48	52.62	52.24	52.36	51.88	51.75	51.41	0.02	↓
Payer, %											
Medicare	63.81	62.48	62.78	63.08	63.29	63.96	64.23	65.47	64.62	0.01	↑
Medicaid	4.58	3.7	3.91	4.38	4.41	4.42	4.71	4.47	6.26	0.01	↑
Private	25.3	27.24	27.41	26.57	25.75	25.47	24.2	23.23	23.53	0.012	↓
Self-pay	3.77	4.34	3.53	3.64	4.06	3.6	4.06	3.98	3.06	0.342	···
Others	2.53	2.25	2.37	2.33	2.49	2.54	2.8	2.85	2.53	0.027	↑
Income percentile											
0–25	24.49	24.44	23.47	23.39	23.22	23.63	25.5	26.03	25.78	0.089	···
26–50	27.14	25.71	29.02	27.87	27.27	25.08	25.08	27.39	29.61	0.776	···
51–75	24.75	26.17	23.61	25.29	24.82	26.21	24.71	24.42	23.1	0.208	···
76–100	23.61	23.68	23.89	23.45	24.69	25.07	24.72	22.15	21.51	0.488	···
Comorbidities, %											
Hypertension	61.82	56.93	58.72	60.98	61.31	62.81	63.01	64.07	65.04	0.008	↑
CHF	24.47	21.91	22.83	23.96	24.69	24.91	24.35	25.73	26.47	0.014	↑
DM	20.98	18.89	19.73	20.56	20.81	21.15	21.75	21.71	22.51	0.01	↑
Valvular disease	13.8	14.65	13.58	13.64	13.17	13.85	13.2	13.63	14.72	0.801	···
CKD	10.24	7.64	8.15	9.16	10.17	10.63	11.17	11.61	12.37	0.008	↑
COPD	20.53	18.67	19.33	20.03	20.33	20.86	20.85	21.57	21.93	0.01	↑
CHA_2DS_2-VASc score, %											
0	8.56	9.66	9.4	8.66	8.7	8.43	8.26	7.87	7.88	0.012	↓
1	13.29	14.03	13.41	13.43	13.48	13.21	13.33	12.78	12.87	0.023	↓
≥2	78.15	76.32	77.19	77.91	77.82	78.36	78.41	79.35	79.24	0.012	↑
Elixhauser Comorbidity Index ≥3, %	61.61	57.24	58.11	60.62	61.08	62.66	62.65	64.14	64.14	0.01	↑
Hospital status, %											
Metropolitan nonteaching	43.35	46.35	47.91	47.14	45.43	44.92	42.38	43.22	31.72	0.017	↓
Metropolitan teaching	38.99	35.43	33.47	34.36	37.29	37.62	39.68	38.78	52.62	0.017	↑
Nonmetropolitan	17.66	18.22	18.62	18.51	17.27	17.46	17.94	18	15.65	0.068	···

Continued

Table 2. Continued

Variable	Total	2007	2008	2009	2010	2011	2012	2013	2014	*P* Value for Trend	Trend*
Hospital region, %											
Northeast	19.3	20.86	19.96	19.57	19.16	19.69	19.34	18.58	17.77	0.02	↓
Midwest	24.18	24.35	23.31	24.19	24.77	24.31	23.81	23.44	25.2	0.659	···
South	37.6	37.51	37.39	37.18	37.11	36.48	37.95	38.61	38.36	0.186	···
West	18.92	17.28	19.35	19.07	18.96	19.52	18.9	19.37	18.68	0.753	···

Values are given as number, percentage, or median (IQR). AF indicates atrial fibrillation; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; ED, emergency department; IQR, interquartile range.
*Only shown for statistically significant trends; $P<0.05$ was considered significant.

Age- and Sex-Standardized Visit Volumes and Admission Rates

The standardized AF ED visit volume increased significantly by an average annual rate of 0.8% from 2007 to 2014. This trend was largely because of the rapid increase in AF ED visits from 2007 to 2011 (2.2% average annual percentage change between 2007 and 2011 versus −1.0% between 2011 and 2014). Although the standardized admission rates for AF decreased by an average of 1.9% per year over the study period, they showed a faster decline between 2012 and 2014 (−0.71% versus −4.88% annual percentage change from 2007 to 2012 versus 2012 to 2014, respectively).

By comparison, age- and sex-standardized volumes for all ED visits grew steadily at an average annual rate of 2.1% throughout the 8-year study period. At the same time, the overall ED admission rates declined by an average of 1.7% per year from 2007 to 2014. The latter half of the study period (2010–2014) saw a sharper decline, and was largely responsible for the downward trend in overall admission rates (−0.4% versus −2.7% annual percentage change from 2007 to 2010 versus 2010 to 2014, respectively).

Predictors of Admission

The correlation of various patient- and hospital-related parameters with admission to the hospital is shown in Table 3. In a univariate analysis, higher admission rates were correlated with age ≥75 years, female sex, Medicare and Medicaid coverage, low income status, several individual comorbidities, Elixhauser Comorbidity Index, and high CHA_2DS_2-VASc score. The results of the multivariable logistic regression models are shown in Table 4. The following patient characteristics were observed to be independent predictors of admission among patients presenting to EDs with a principal diagnosis of AF: advanced age (≥75 years), congestive heart failure, diabetes mellitus, hypertension, valvular heart disease, chronic kidney disease, chronic pulmonary disease, and income percentile. Among hospital-level variables, hospital region was a significant predictor of admission for AF ED visits. Moreover, hospitals in metropolitan areas had a 1.41-fold higher odds of admission compared with nonmetropolitan areas (Table 4).

Hospital Charges

In 2007, AF hospitalizations accounted for 1.12% of $530 billion in aggregate inpatient charges (the "national bill") in the United States. In 2014, this number increased to 1.22% of $828 billion. In every study year, the estimated charges for patients with AF who were admitted to the hospital were

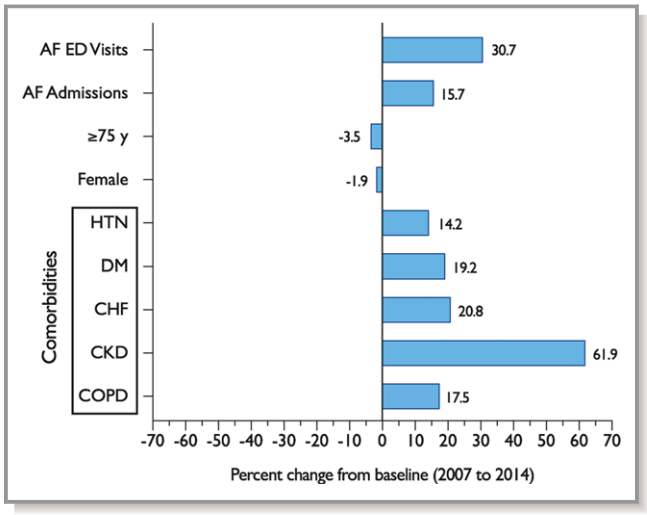

Figure 1. Changes in emergency department (ED) visits for atrial fibrillation (AF), admission rates, baseline patient characteristics, and comorbidities between 2007 and 2014. The percentage change in ED visits and hospital admissions as well as patient characteristics and major comorbidities are shown. Over the study period, there was a significant trend toward sicker patients presenting to the ED with AF, with an increasing prevalence of hypertension (HTN), diabetes mellitus (DM), congestive heart failure (CHF), chronic kidney disease (CKD), and chronic obstructive pulmonary disease (COPD).

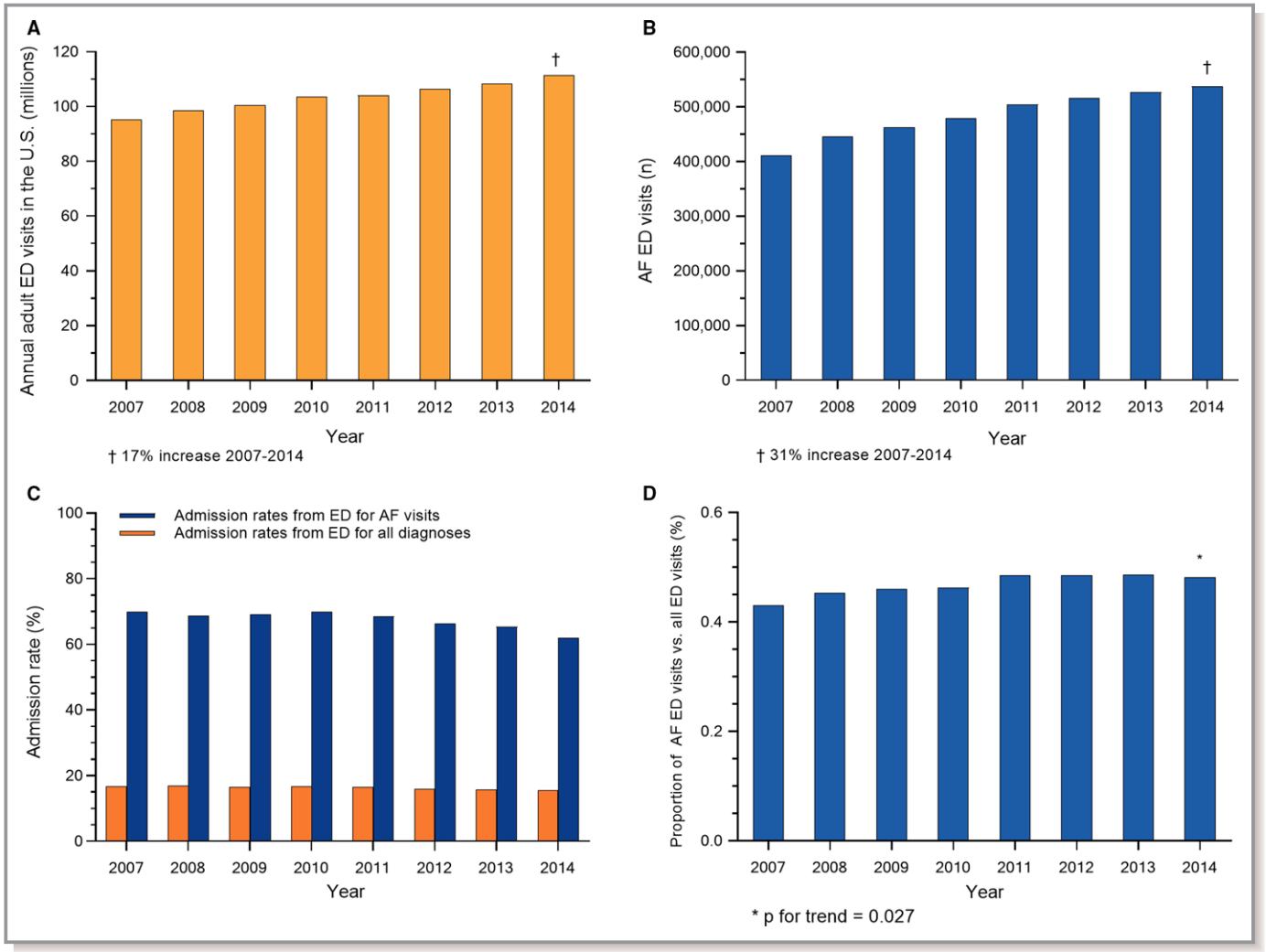

Figure 2. Trends in adult emergency department (ED) visits and atrial fibrillation (AF) ED visits in the United States (2007–2014). The annual volume of ED visits for AF increased significantly from 2007 to 2014, whereas the admission rates gradually declined during the same period. For comparison, all ED visits and admission trends are displayed.

significantly higher than for patients with AF who were discharged from the ED. The total adjusted annual charges for admitted patients with AF increased by 37% from $7.39 billion in 2007 to $10.1 billion in 2014 (Figure 3). As shown in Figure 4, the adjusted median per patient charges for hospitalization increased significantly from $17 317 in 2007 to $22 113 in 2014 ($P_{trend}$=0.008).

Discussion

In this repeated cross-sectional analysis of US ED data, we identified a weighted total of ≈3.9 million ED visits with AF as a principal diagnosis between 2007 and 2014. Admission rates for AF remained stable at ≈70% until 2010 to 2011, after which they declined to a low of 62% in 2014. Despite the decline in AF admission rates, the annual AF hospitalization volume increased 16% over the study period from 288 225 in 2007 to 333 570 in 2014, because of a continual increase in total annual ED visits for AF. This trend, together with a 27.7% increase in median per-patient hospitalization charges, contributed to a significant growth in the economic burden associated with AF in the United States over the study period.

The clinical characteristics described in this study were consistent with prior reports on ED visits for AF in the United States,[9,16,19] as were the admission rates of up to 70% before 2011.[9,19–21] Despite the significant reduction in AF hospitalization rates in the latter half of the study period, 2 important trends persist. First, the surge in absolute numbers of ED visits for AF has resulted in a steady annual increase in the total volume of hospital admissions for AF. Second, hospitalization rates for AF remain surprisingly high, almost twice that seen in Canada[22,23] and Europe.[24] Even a decade later (fiscal year 2014), and with similar patient characteristics and comorbidities, the AF admission rates in the United States are 23% higher than those in Canada in 2004.

Table 3. Admission Rates of Patients With AF From EDs in the United States From 2007 to 2014

Variables	Admission Rate, %	Unadjusted OR for Admission	95% CI	*P* Value
All ED visits	67.34	…	…	…
Age group, y, %				
≤74	63.25	Reference	…	…
≥75	72.97	1.57	1.55–1.58	<0.001
Sex, %				
Male	65.17	Reference	…	…
Female	69.35	1.21	1.19–1.22	<0.001
Payer, %				
Medicare	71.18	Reference	…	…
Medicaid	71.99	1.05	1.02–1.07	<0.001
Private	57.67	0.55	0.54–0.56	<0.001
Self-pay	62.48	0.67	0.65–0.68	<0.001
Others	67.05	0.85	0.82–0.87	<0.001
Income status, percentile				
0–25	71.29	Reference	…	…
26–50	67.34	0.84	0.83–0.85	<0.001
51–75	65.77	0.78	0.77–0.79	<0.001
76–100	64.78	0.73	0.72–0.74	<0.001
Hospital teaching status, %				
Nonmetropolitan	60.99	Reference	…	…
Metropolitan nonteaching	68.45	1.39	1.37–1.41	<0.001
Metropolitan teaching	68.98	1.38	1.37–1.40	<0.001
Hospital region, %				
Northeast	72.88	Reference	…	…
Midwest	65.29	0.71	0.70–0.72	<0.001
South	72.09	0.96	0.95–0.97	<0.001
West	54.86	0.46	0.45–0.47	<0.001
Elixhauser Comorbidity Index, %				
<3	42.12	Reference	…	…
≥3	83	6.72	6.66–6.80	<0.001
CHA_2DS_2-VASc, score %				
0	41.26	Reference	…	…
1	52.96	1.6	1.57–1.63	<0.001
≥2	72.65	3.77	3.71–3.83	<0.001
Comorbidities, %				
Hypertension	76.13	2.8	2.78–2.83	<0.001
Congestive heart failure	88.38	4.93	4.85–5.00	<0.001
Diabetes mellitus	78.63	2.03	2.00–2.06	<0.001
Valvular disease	88.61	4.36	4.28–4.44	<0.001
Chronic kidney disease	87.24	3.63	3.56–3.71	<0.001
Chronic pulmonary disease	85.21	3.42	3.37–3.47	<0.001

AF indicates atrial fibrillation; CI, confidence interval; ED, emergency department; OR, odds ratio.

There are noteworthy findings when AF ED visits are compared with the all-cause ED visits (Figure 2). Our study spans the years when the Affordable Care Act was enacted. Between 2007 and 2014, there was a steady 13% increase in ED visit volumes in the United States. However, the admission rates declined (Figure 2D). This decline has been previously ascribed to the Hospital Readmissions Reduction Program, a provision of the Affordable Care Act that penalizes hospitals with higher-than-expected readmission rates for targeted conditions.[25] Although the Hospital Readmissions Reduction Program did not start until 2012, studies show that many hospitals implemented strategies to reduce readmission rates starting in 2009, and that readmission rates decreased quickly after passage of the Affordable Care Act in March 2010.[25] In comparison to the 6.6% decrease in hospital admissions of all ED visits, admissions for AF decreased by 11.5% during the same period.

In an attempt to understand the contributors to the observed changes in admission rates, we reviewed the trends in baseline patient and hospital characteristics (Table 2), none of which provided an explanation for the significant decline in admission rates after 2011. Interestingly, this decline in admission rates occurred in parallel with the introduction of Novel Oral Anticoagulants in the United States after US Food and Drug Administration approval of Pradaxa (dabigatran) in late 2010, followed by Xarelto (rivaroxaban) in 2011 and Eliquis (apixaban) in 2012. A limitation of the NEDS database is the absence of pharmacy data, which precluded a direct assessment of a potential correlation between the increasing use of NOACs and a reduction in ED admission rates for AF.

In 2006, Coyne et al estimated the total direct annual cost for treatment of patients with AF in the United States to be $6.65 billion, with hospitalizations accounting for the largest share of this cost.[7] On the basis of another analysis from 2008, Lee et al reported that the incremental direct treatment costs for Medicare beneficiaries with AF were higher than previously reported, partly because of the significantly higher proportion of these patients experiencing strokes and congestive heart failure.[10] Extrapolating these data from a random 5% national sample of Medicare beneficiaries to the entire Medicare population results in a projected annual cost of $15.7 billion for the treatment for newly diagnosed AF.[10] In our study, 64% of all ED visits with a principal diagnosis of AF were Medicare patients, of whom 71% were admitted to the hospital, compared with 67% of the overall population. The significant increase in the economic burden of hospital admissions for AF is driven by a combination of the increasing total number of ED visits and associated hospital admissions for AF, and a 27.7% increase in the median per-patient hospitalization charges over the study period, all of which are reflected in the 9% increase in the share of the national bill (aggregated annual ED charges) attributable to AF during the 2007 to 2014 period.

Table 4. Multivariable Logistic Regression: Independent Patient- and Hospital-Level Predictors of Admission for Patients Who Presented to EDs for AF in the United States From 2007 to 2014

Predictor	Adjusted Odds Ratio	95% CI	*P* Value
Model 1 (C-statistic=0.76)*			
Age group, y			
≤74	1.00 (Reference)	NA	. . .
≥75	1.14	1.13–1.16	<0.001
Female sex	1.01	0.99–1.02	0.528
Comorbidities			
Hypertension	2.16	2.14–2.19	<0.001
Congestive heart failure	3.43	3.38–3.49	<0.001
Diabetes mellitus	1.38	1.36–1.40	<0.001
Valvular disease	3.19	3.12–3.26	<0.001
Chronic kidney disease	2.21	2.16–2.27	<0.001
Chronic pulmonary disease	2.46	2.42–2.50	<0.001
Income status, percentile			
0–25	1.00 (Reference)	NA	. . .
26–50	0.98	0.96–0.99	0.012
51–75	0.95	0.93–0.96	<0.001
76–100	0.89	0.88–0.91	<0.001
Hospital status			
Nonmetropolitan	1.00 (Reference)	NA	. . .
Metropolitan nonteaching	1.41	1.34–1.49	<0.001
Metropolitan teaching	1.41	1.33–1.50	<0.001
Hospital region			
West	1.00 (Reference)	NA	. . .
Northeast	2	1.81–2.22	<0.001
Midwest	1.36	1.24–1.48	<0.001
South	1.73	1.59–1.89	<0.001
Model 2 (C-statistic=0.66)†			
CHA_2DS_2-VASc score			
0	1.00 (Reference)	NA	. . .
1	1.61	1.58–1.65	<0.001
≥2	3.74	3.67–3.82	<0.001

AF indicates atrial fibrillation; CI, confidence interval; ED, emergency department; NA, not applicable.
*Adjusted for insurance status, hospital ED visit volume, and calendar year.
†Adjusted for income status, insurance status, hospital region, hospital teaching status, hospital ED visit volume, and calendar year. Separate model was required to avoid interaction between multiple variables.

There is a growing body of evidence that supports a revised paradigm for the management of AF in the ED. This includes early assessment and cardioversion, followed by a brief

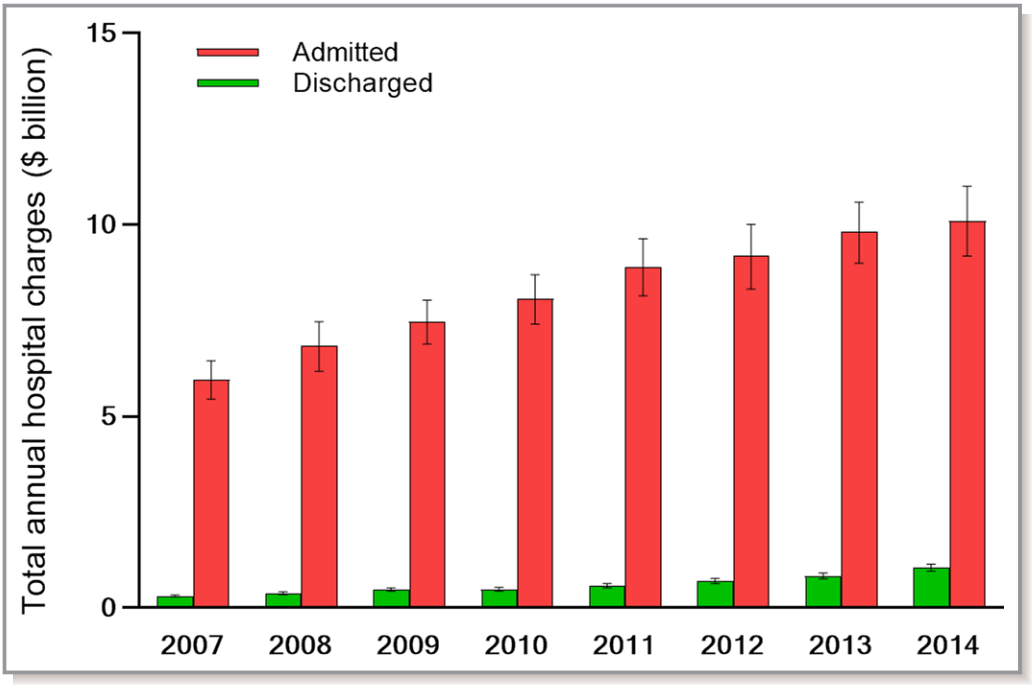

Figure 3. Total annual charges for atrial fibrillation (AF)–related emergency department (ED) visits, resulting in discharge or hospital admissions in the United States (2007–2014). The total annual charges for AF ED visits resulting in discharge and admissions increased significantly from 2007 to 2014. The significant increase in the economic burden of hospital admissions for AF is driven by a combination of the increasing total number of ED visits and hospital admissions and a 37% increase in the median per-patient hospitalization charge over the study period.

observation period, and subsequent discharge of stable patients from the ED. Published data support these new paradigms as safe and logistically feasible alternatives to inpatient management of appropriately selected patients with AF.[11–15] The implementation of these strategies has been shown to result in substantial reductions in hospital admission rates and costs.[13–15] However, studies describing these new approaches are relatively small, and the guidelines for management of AF in the ED are not as well validated or widely adopted as other aspects of AF management.[26,27] Given the epidemic proportions of AF incidence and prevalence predicted for the coming decades,[2,28,29] aggressive interventions on a national level are warranted to prevent unnecessary hospital admissions and reduce the use of valuable and limited healthcare resources.

The present study has several limitations. The data were collected from an administrative database, which may have errors associated with coding inaccuracies and reporting bias. Another limitation of the NEDS database is the lack of pharmacy data, which precludes a direct examination of the effect of NOACs, as well as rate versus rhythm control strategy implementation, on admission rates and length of hospital stay. The database also makes it impossible to distinguish between patients presenting with new-onset AF and those with a history of AF, which could have different clinical characteristics and outcomes. During the period of this study, some hospitals implemented ED Observation Status as a third category for disposition of patients. Because it is not clear whether these observations were coded as discharge or admission in this database, it is possible that the admission rates may have been partially confounded. Another limitation is the lack of actual cost data, which exceeds charges. The NEDS database provides only service charges. Although there could be substantial differences between calculated charges and costs, comparing the results of this study with the report by Coyne et al[7] shows relatively small differences between the 2 measures. We believe that these limitations are favorably balanced by the comprehensive real-world data that this database provides.

Conclusions

Among a weighted total of 3 886 520 ED visits for AF in the United States between 2007 and 2014, the annual volume of ED visits and hospital admissions continued to increase, despite a gradual reduction in admission rates after 2011. This trend, together with a substantial increase in the median hospital charge per patient over the 8 years of this study, has contributed to an alarming growth in the economic burden associated with AF in the United States. These data underscore

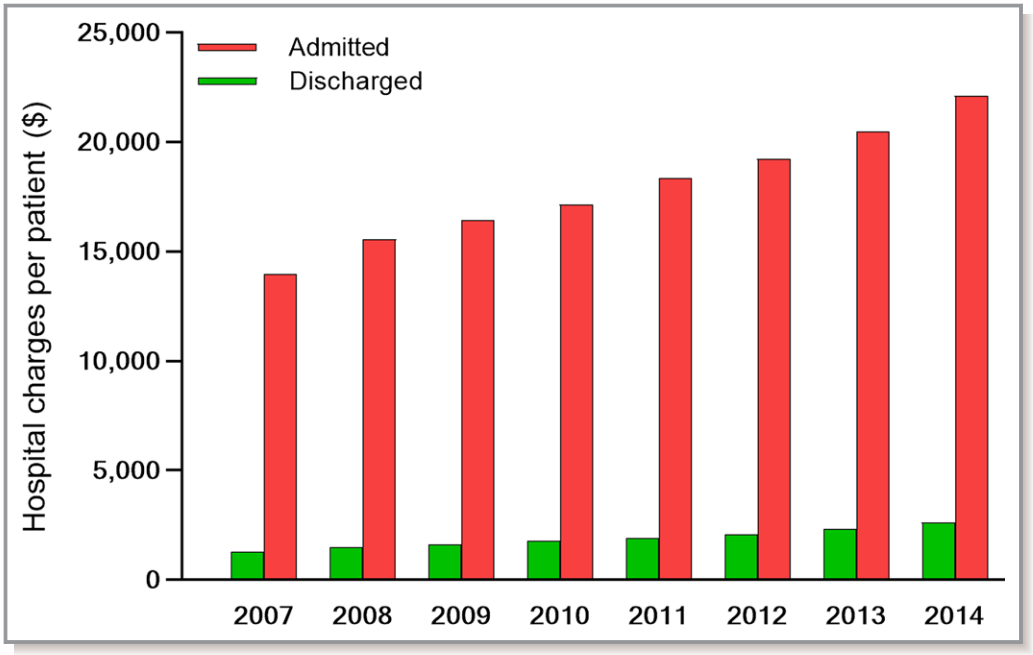

Figure 4. Median hospital charges (adjusted for inflation) per patient: atrial fibrillation (AF) emergency department visits resulting in discharge or hospital admission. The adjusted median per-patient hospital charges for admitted patients with AF increased significantly in the United States from 2007 to 2014. This was one of the major contributors to the significant increase in the total AF hospitalization economic burden during the study period.

the need for widespread implementation of proven intervention strategies aimed at improving the management of patients with AF, reducing the volume of ED visits, and substantially reducing admission rates for AF in the United States.

Disclosures

No relevant disclosures.

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SUPPLEMENTAL MATERIAL

Data S1.

Supplemental Methods

The NEDS is a 20 percent stratified sample of the target universe. The target universe for the NEDS was community (non-Federal short-term general or specialty), non-rehabilitation hospital-based EDs in the US that met the following conditions: (1) were included in the AHA Annual Survey Database, and (2) reported total annual ED visits. Non-rural hospitals with less than ten total ED visits per year were excluded. Hospitals that met the above criteria and were located in any of the HCUP Partner States, and had less than 90 percent ED admission rates, provided the discharge records that were used in the final sample. Furthermore, hospitals were stratified into stratums based on different hospital characteristics (e.g., region, ownership, trauma designation, etc.). The stratification method helps in creating a database containing a "microcosm" of EDs in the United States with similar characteristics and hospital-based ED distribution as the target universe. After the sampling and stratification, discharge weights were calculated as the number of ED visits from the target universe, divided by the number of visits from the sample hospitals which were included in the NEDS. Hence, each record represents the number of universe ED visits in its stratum during that year[1]. Below is the formula presented on the HCUP website [1]:

$$[DNs(universe) \div ADNs(sample)] * (4 \div Qi)$$

- DNs(universe): the number of ED visits in the universe within stratum
- ADNs(sample): the number of adjusted ED visits from sample hospitals
- Qi: the number of quarters of ED visits contributed by hospital i to the NEDS

Supplemental Reference:

1. “Description of NEDS Files.” NEDS Database Documentation Archive, www.hcup-us.ahrq.gov/db/nation/neds/nedsarchive.jsp.