Contemporary Trends of Hospitalization for Atrial Fibrillation in the United States, 2000 Through 2010

Implications for Healthcare Planning

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Background—Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia. The associated morbidity and mortality make AF a major public health burden. Hospitalizations account for the majority of the economic cost burden associated with AF. The main objective of this study is to examine the trends of AF-related hospitalizations in the United States and to compare patient characteristics, outcomes, and comorbid diagnoses.

Methods and Results—With the use of the Nationwide Inpatient Sample from 2000 through 2010, we identified AF-related hospitalizations using International Classification of Diseases, 9th Revision, Clinical Modification code 427.31 as the principal discharge diagnosis. Overall AF hospitalizations increased by 23% from 2000 to 2010, particularly in patients ≥65 years of age. The most frequent coexisting conditions were hypertension (60.0%), diabetes mellitus (21.5%), and chronic pulmonary disease (20.0%). Overall in-hospital mortality was 1%. The mortality rate was highest in the group of patients ≥80 years of age (1.9%) and in the group of patients with concomitant heart failure (8.2%). In-hospital mortality rate decreased significantly from 1.2% in 2000 to 0.9% in 2010 (29.2% decrease; \( P < 0.001 \)). Although there was no significant change in mean length of stay, mean cost of AF hospitalization increased significantly from $6410 in 2001 to $8439 in 2010 (24.0% increase; \( P < 0.001 \)).

Conclusions—Hospitalization rates for AF have increased exponentially among US adults from 2000 to 2010. The proportion of comorbid chronic diseases has also increased significantly. The last decade has witnessed an overall decline in hospital mortality; however, the hospitalization cost has significantly increased. (Circulation. 2014;129:2371-2379.)

Key Words: atrial fibrillation ▪ cost ▪ hospitalization

Atrial fibrillation (AF) is a major global public health challenge. The prevalence of AF has been projected to increase to 15.9 million by the year 2050, with more than half of these patients ≥80 years of age, leading to substantial public health and economic burden.\(^2\) AF increases the risk of mortality and morbidity resulting from stroke, congestive heart failure, and impaired quality of life, explaining its enormous socioeconomic implications.\(^3\) The economic burden associated with AF is growing considerably and is driven primarily by the rising cost of hospitalizations.\(^5\) The total cost of nonvalvular AF care was estimated to be $6.7 billion per year in 2005 in United States, and three quarters of this cost is related to inpatient care.\(^5\) Therefore, a meticulous understanding of the trends in AF-related hospitalizations is critical for appropriate healthcare planning and for reducing demands on the healthcare system. Furthermore, a stratified nation-level study is likely to identify peculiar patterns across subpopulations and geographic regions, which may help in the recognition of specific locations or vulnerable groups for targeted healthcare interventions. There is paucity of data on AF hospitalization trends on a national scale. The present study was therefore designed to perform a contemporary evaluation of the burden of AF-related hospitalizations. The aims of the study were to determine temporal trends of AF hospitalizations and to assess the effect of comorbid diagnoses and demographics on in-hospital mortality, length of stay, and total cost of care during the hospitalization.

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Arrhythmia/Electrophysiology

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Methods

Data Source
The Nationwide Inpatient Sample (NIS), created by the Agency for Healthcare Research and Quality, is the largest all-payer inpatient database in the United States. It contains all discharge data from >1200 hospitals located across 45 states. The NIS is available yearly beginning with 1988, and these data have been used to identify, track, and analyze national trends in healthcare use, healthcare access, disparity of care, hospitalization rate, and outcomes for various diagnoses and major procedures. The NIS was designed to approximate a 20% stratified random sample of US community hospitals and provides sampling weights to calculate national estimates. Each individual hospitalization is deidentified and maintained in the NIS as a unique entry with 1 primary discharge diagnosis and <24 secondary diagnoses during that hospitalization. Each entry also carries information on demographic details, insurance status, comorbidities, primary and secondary procedures, hospitalization outcome, length of stay, and cost of care. The NIS contains the clinical and resource use information included in a typical discharge summary, with safeguards to protect the privacy of individual patients, physicians, and hospitals (as required by the data sources).

Annual data quality assessments of the NIS are performed, which guarantee the internal validity of the database. Furthermore, comparisons against the following data sources strengthen the external validity of the NIS: the American Hospital Association Annual Survey Database, the National Hospital Discharge Survey from the National Center for Health Statistics, and the MedPAR inpatient data from the Centers for Medicare and Medicaid Services.

Study Design and Cohorts
This was a cross-sectional study using the NIS database for the years between 2000 and 2010. We studied all hospitalizations from 2000 to 2010 with a primary diagnosis of AF, identified with validated International Classification of Diseases, 9th Revision, Clinical Modification code 427.31. We included all patients ≥18 years of age. To study the demographics of AF hospitalizations, we excluded all patients with missing age, sex, admission or discharge date, and in-hospital mortality status. We further excluded all entries with the same admission and discharge date (length of stay=0) because such events might not have truly represented hospital stays for an acute condition. Similar methodology has been used in prior studies. Disposition to another facility includes transfer to skilled nursing facility, intermediate-care facility, and nursing homes.

Comorbidities associated with AF hospitalization were identified by Agency for Healthcare Research and Quality comorbidity measures. These comorbidity measures identify different comorbidities by using International Classification of Diseases, 9th Revision, Clinical Modification diagnoses and the diagnosis-related group in effect on the discharge date. These comorbidities are not directly related to the principal diagnosis or the main reason for admission and are likely to have originated before the hospital stay.

To calculate estimated cost of hospitalizations, the NIS data were merged with cost-to-charge ratios available from the Healthcare Cost and Utilization Project. We estimated the cost of each inpatient stay by multiplying the total hospital charge by the cost-to-charge ratio. Adjusted cost for each year was calculated in terms of the 2010 cost after adjustment for inflation according to the latest Consumer Price Index data released by US government on January 16, 2013.

Statistical Analysis
Stata IC 11.0 (Stata Corp, College Station, TX) and SAS 9.2 (SAS Institute Inc, Cary, NC) were used for the analyses, which accounted for the complex survey design and clustering. Because NIS represents a 20% stratified random sample of US hospitals, analyses were performed using hospital-level discharge weights provided by the NIS to obtain national estimates of AF hospitalizations. AF hospitalizations per 1 million US population were calculated by dividing the number of AF hospitalizations available in the NIS data set in a given year divided by 20% of the US census population ≥18 years of age for that year. AF hospitalizations were also calculated in subgroups of age (18–34, 35–49, 50–64, 65–79, ≥80 years), sex, race (white, nonwhite, and missing), insurance status (Medicare/Medicaid, private insurance, self-pay/other), and hospital location in different US regions (Northeast, Midwest, South, West). For categorical variables like annual change in AF hospitalization rate and in-hospital mortality, the χ² test of trend for proportions was used with the Cochrane Armitage test via the “ptrend” command in Stata. For continuous variables like cost of hospitalization, the nonparametric test for trend by Cuzick (which is similar to Wilcoxon rank-sum test) using the “npptrend” command in Stata was used.

Results

AF Hospitalizations, Demographics, and Comorbidities
A total of 3960011 hospitalizations for AF as the primary discharge diagnosis were reported in the United States from 2000 to 2010. AF hospitalizations increased progressively from 312926 in 2000 to 409854 in 2010. Patient characteristics are summarized in Table 1. AF patients were predominantly white (64.9%) and >65 years of age (69.8%). There were slightly more hospitalizations in women than men, but the difference in the sex ratio has been declining; hospitalization for female versus male patients decreased from 54.2% versus 45.8% in 2000 to 52.6% versus 47.4% in 2010. The majority (70%) of AF hospitalizations were associated with Medicare/Medicaid as the primary payer. In terms of geographic distribution of admissions, the hospitals in the South constitute the highest percentage of AF hospitalizations (38.5%), followed by the Midwest (24.9%), Northeast (22.2%), and West (14.4%). The most frequent coexisting conditions in patients admitted with AF were hypertension (60.0%), diabetes mellitus (21.5%), and chronic pulmonary disease (20.0%). From 2000 to 2010, the prevalence of several comorbidities increased significantly. The rate of increase was highest for renal failure: In 2000, the prevalence of chronic renal failure was 3.3%, which increased 4-fold and reached 12.3% by 2010.

Trends in AF Hospitalizations
The AF hospitalization rate increased significantly from 1552 to 1812 per 1 million US population per year from 2000 to 2010 (relative increase, 14.4%; P<0.001; Table 2). The hospitalization rate has increased across all age groups except for a nonstatistically significant decline in 18- to 34-year age group (relative decrease, 3.1%; P=0.686). The magnitude of increase in AF-related hospitalization was observed in the following age groups in descending order: 35 to 49 years (relative increase, 16.6%; P<0.001), ≥80 years (relative increase, 15.2%; P<0.001), 50 to 64 years (relative increase, 10.1%; P<0.001), and 65 to 79 years (relative increase, 0.9%; P<0.001; Table 2). The AF hospitalization rate was higher in women and whites throughout the study period. However, the relative rates of increase in AF hospitalizations over the year were higher in male compared with female patients (16.9% versus 12.1%; P<0.001) and in nonwhites compared with whites (35.1% versus 25.3%; P<0.001). The mean age of the patients hospitalized with a principal diagnosis of AF was 70 years. The mean age for men was 66 years and for women was 74 years. In a sensitivity analysis, we found that the female-to-male ratio is different in those ≥65 and <65 years. In the ≥65-year age
### Table 1. Baseline Characteristics of the Patients With AF Hospitalizations

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<td>&lt;0.001</td>
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<tr>
<td>Liver and biliary diseases</td>
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<td>&lt;0.001</td>
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<tr>
<td>Renal failure</td>
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<td>&lt;0.001</td>
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<tr>
<td>Tumor and other lymphoma</td>
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<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight loss</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>In-hospital mortality, %</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
<td>1.0</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>1.1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; AHRQ, Agency for Healthcare Research and Quality; and HMO, health maintenance organization.

*Variables are AHRQ comorbidity measures.
†Neurological disorders include hemiplegia, paralysis, and other neurological disorders.
‡Psychological disorders include depression, psychosis, and other major psychological disorders.
§Rheumatologic disorders include rheumatoid arthritis and other collagen vascular disorders.

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group, the female-to-male ratio was 61% versus 39%; in the <65-year age group, the ratio was 34% versus 66% (Figure 1).

**In-Hospital Mortality**

Overall in-hospital mortality associated with AF hospitalizations was 1%. Overall inpatient mortality associated with AF hospitalizations decreased significantly from 1.2% in 2000 to 0.9% in 2010 (relative decrease, 29.2%; \( P < 0.001 \)). Across the age groups, the mortality rate was highest in ≥80-year age group at 1.9%. The mortality rate was slightly higher in female patients (1.1%), nonwhites (1.2%), and patients with Medicare/Medicaid insurance (1.3%). In terms of comorbid conditions associated with AF hospitalization, patients with heart failure (8.2%) and chronic renal failure (2.6%) had significantly higher mortality rates compared with patients without these comorbidities (Table 3).

**Length of Stay, Cost, and Disposition**

The median length of stay was 3 days (interquartile range, 2–5 days). During the study period, there was no statistically significant change in mean or median length of stay.

After adjustment for inflation, the mean cost of AF hospitalizations increased significantly from $6410 in 2001 to $8439 in 2010 (relative increase, 24.0%; \( P < 0.001 \)) (Figure 2). This represents an absolute increase in annual national cost from approximately $2.15 billion in 2001 to $3.46 billion in 2010. The mean cost of care was highest if AF hospitalization was associated with heart failure ($33,161) and valvular disorders ($28,030; Table 4).

For the disposition status analysis, we excluded the patients who were admitted from any other facility. The percentage of patients discharged home decreased over the last decade from 80.1% in 2000 to 70.2% in 2010. There was a corresponding increase in discharges to another facility (8.1% in 2000 to 11.5% in 2010) and need for home health care (6.7% to 13.1%). This is shown in Figure 3. Approximately one fourth of the patients (25.8%) were discharged to long-term care institution if AF hospitalization was complicated by acute ischemic stroke.

Length of stay and cost of AF hospitalizations increased proportionately with an increase in CHADS2 score (\( P < 0.01 \), as shown in Figure 4.

**Discussion**

This study reports contemporary data of AF hospitalizations over an 11-year period in the United States. The main findings of our analysis of the largest database available are the following: (1) There was a significant increase in AF hospitalizations over the study period; (2) most admissions occurred in patients ≥65 years of age, and patients >80 years of age...
exhibited an exponential increase in admissions and greater in-hospital mortality compared with other age groups; (3) mortality associated with AF hospitalizations decreased significantly except in patients with heart failure, who exhibited an increase in mortality; (4) the length of stay remained unchanged but the cost of care increased significantly over this time period after adjustment for inflation; and (5) there was an increasing trend for disposition of patients to another facility and need for home health care.

Our contemporary finding of increasing AF hospitalization rates is in agreement with other national and international reports. The rise in AF admission is likely due to aging of the general population and the increasing prevalence of risk factors like hypertension, obesity, sleep apnea, and diabetes mellitus. On further evaluation of the age differences between these hospitalizations, we found that more than two thirds of the patients were ≥65 years of age, which is consistent with another national study. Patients ≥80 years of age made up the largest number of admissions per 1 million US population for any age group throughout the study. This age group had an exponential increase in the number of hospitalizations from 9361 per 1 million population per year in 2000 to 11,045 per 1 million population per year in 2010. These figures are alarming because the number of people ≥80 years of age is expected to increase from 11.4 million in 2008 and to 19.5 million in 2030, which in turn will lead to an enormous increased burden on the public health system and associated cost of care. In addition, we found that the mortality in this age group was considerably higher than in the rest of the population. The increasing number of AF hospitalizations, together with the higher in-hospital mortality in this age group, highlights the fact that AF may not be an entirely benign condition in the elderly.

Overall, women had more AF-related hospitalizations than men; however, after adjustment for age, young men (<65 years of age) had more AF hospitalizations than young women and elderly women (≥65 years of age) had more AF-related hospitalizations than elderly men. This sex-specific pattern of an
increase in the incidence of AF admissions with age in men and women and a reversal in the sex ratio after 65 years of age is very similar to that reported in previous cross-sectional studies. An encouraging finding of our study is the fact that mortality associated with AF hospitalizations has decreased in the general population. However, AF patients with concomitant

Table 4. Adjusted Cost for AF Hospitalization

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Relative Change, %</th>
<th>P Value for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations, n</td>
<td>335373</td>
<td>338231</td>
<td>332484</td>
<td>322121</td>
<td>341001</td>
<td>368692</td>
<td>364300</td>
<td>412723</td>
<td>422302</td>
<td>409854</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>6410</td>
<td>7237</td>
<td>7405</td>
<td>7779</td>
<td>8168</td>
<td>8257</td>
<td>8217</td>
<td>8197</td>
<td>8151</td>
<td>8439</td>
<td>24.0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
| Overall AF hospitalization cost in US, $  
Age |  
18–34 y | 4222 | 4868 | 4887 | 5253 | 6309 | 5885 | 6065 | 5692 | 5334 | 6092 | 30.7 | <0.001 |  
35–49 y | 5344 | 6032 | 6254 | 6847 | 7659 | 7686 | 7624 | 7712 | 7439 | 7799 | 31.5 | <0.001 |  
50–64 y | 5960 | 6861 | 7003 | 7597 | 8385 | 8283 | 8574 | 8600 | 8541 | 8740 | 31.8 | <0.001 |  
65–79 y | 6554 | 7335 | 7678 | 7958 | 8325 | 8401 | 8344 | 8322 | 8365 | 8729 | 24.9 | <0.001 |  
≥80 y | 6851 | 7764 | 7728 | 8010 | 8026 | 8314 | 8036 | 7959 | 7875 | 8093 | 15.3 | <0.001 |  
| Sex |  
Male | 6399 | 7373 | 7600 | 7950 | 8571 | 8587 | 8644 | 8498 | 8523 | 8856 | 27.7 | <0.001 |  
Female | 6420 | 7124 | 7239 | 7634 | 7806 | 7956 | 7828 | 7926 | 7815 | 8070 | 20.5 | <0.001 |  
| Primary payer |  
Medicare/Medicaid | 6715 | 7658 | 7765 | 8035 | 8230 | 8453 | 8288 | 8275 | 8232 | 8503 | 21.0 | <0.001 |  
Private insurance, including HMO | 5557 | 6102 | 6441 | 7075 | 8031 | 7770 | 8120 | 8090 | 8092 | 8327 | 33.3 | <0.001 |  
Self-pay/no charge/other | 6337 | 6999 | 6999 | 7570 | 7963 | 8003 | 7797 | 7709 | 7410 | 8167 | 22.4 | <0.001 |  
| Hospital region |  
Northeast | 8130 | 8727 | 8879 | 10005 | 9660 | 9749 | 9677 | 9333 | 8995 | 9495 | 14.4 | <0.001 |  
Midwest or North Central | 6102 | 7028 | 7096 | 7090 | 7962 | 7608 | 7615 | 7803 | 8068 | 8432 | 27.6 | <0.001 |  
South | 5813 | 6440 | 6599 | 6928 | 7096 | 7618 | 7396 | 7385 | 7399 | 7538 | 22.9 | <0.001 |  
West | 6429 | 7616 | 8206 | 7628 | 8557 | 9147 | 9246 | 9930 | 9428 | 9690 | 33.7 | <0.001 |  
| AHRQ comorbidity measures |  
Renal failure |  
No | … | 7086 | 7253 | 7623 | 7988 | 7993 | 7973 | 7978 | 7938 | 8168 | 13.3 | <0.001 |  
Yes | … | 11589 | 11502 | 11657 | 11595 | 11211 | 10580 | 10626 | 9816 | 10348 | −12.0 | <0.001 |  
History of congestive heart failure |  
No | … | 6964 | 7271 | 7648 | 8054 | 8152 | 8122 | 8111 | 8056 | 8329 | 16.4 | <0.001 |  
Yes | … | 30066 | 36392 | 36735 | 36007 | 37503 | 37781 | 30000 | 27512 | 33638 | 10.6 | 0.030 |  
AF indicates atrial fibrillation; AHRQ, Agency for Healthcare Research and Quality; and HMO, health maintenance organization. Cost data are available only after 2001.
heart failure may exhibit a different clinical course than the rest of AF patients. Our findings of increased in-hospital mortality in patients with AF and heart failure highlight the notions that these patients carry much worse prognosis and that preventive measures should be instituted early to reduce the number of hospitalizations. It is still not clear whether this subgroup would derive benefit from aggressive rate control or early rhythm control. However, results from prospective studies and a meta-analysis suggest that when these patients undergo catheter ablation for AF, they have an objective improvement in functional class and systolic function.

The mean length of hospital stay remained unchanged over the time period of 2000 to 2010; however, the total cost of care increased tremendously over this time frame. The increasing number of hospitalizations, aging population, patient complexity, and increasing trend for disposition to another facility are some of the drivers of the increasing cost. This represents a staggering economic burden on the healthcare system and serves as an unequivocal reminder that hospitalizations represent the largest part of the total cost for AF treatment. Medicare was consistently the major payment source, reflecting that mainly the elderly population drove the increase in hospitalizations for AF. Future efforts to reduce this economic burden must be focused on limiting hospitalizations and lengths of stay. Certain interventions such as emergency room observation units versus hospital admission, rate control versus rhythm control, and use of low-molecular-weight heparin versus unfractionated heparin have previously been described as potential means to reduce the cost associated with the treatment of AF.

Nearly 38% of the hospitalizations occurred in Southern region of United States, which also coincides with the “stroke belt.” The Southeastern region of the United States is well known for an excess incidence of stroke and its risk factors such as hypertension, diabetes mellitus, and heart failure compared with the rest of the country.

Limitations
Although administrative databases are increasingly used for clinical research, such studies are potentially susceptible to errors arising from coding inaccuracies. The diagnosis of AF and the presence of comorbidities were based on the presence of administrative codes; however, administrative codes have been shown to be highly specific for cardiovascular diagnoses and risk factors. International Classification of Diseases, 9th Revision, Clinical Modification code 427.31 has been validated for AF in the administrative database in prior studies, and the International Classification of Diseases coding for AF did not change over the study period. We were unable to identify new-onset AF and to define the duration and type (paroxysmal versus persistent) of AF. If AF is accompanied by other serious conditions like heart failure or stroke, then these...
conditions often end up as the primary diagnosis. This could underestimate AF hospitalization frequency and its sequelae. The NIS considers each hospitalization as separate entry, so it is not possible to separate index cases from readmissions. This could result in an overestimation of the number of admissions. Our study focused on AF hospitalizations and did not include any data pertaining to AF care in an outpatient setting or emergency departments; therefore, it may underestimate the overall AF incidence rates. The nature of the data allowed us to examine only in-hospital mortality; hence, the study did not have any long-term follow-up outcomes. Despite these limitations, the present study has important strengths, including a real-world large sample size and the absence of selection bias associated with clinical trials.

Conclusions
We report contemporary evidence suggesting a persistent increase in AF hospitalizations with an associated increase in hospitalization costs. Prevention of AF hospitalizations and an effective outpatient management should be pursued to reduce the burden on the healthcare system.

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No study-specific funding was used to support this work. The authors are solely responsible for the study design, conduct, and analyses and for drafting and editing of the manuscript and its final contents. No statement should be construed as an official position of the Agency for Healthcare Research and Quality or the US Department of Health and Human Services.

Disclosures
Dr Mitrani has consultant relationships with Medtronic Inc and St. Jude Medical. The other authors report no conflicts.

References
Atrial fibrillation (AF) is one of the most frequently encountered arrhythmias in the hospital. A multidisciplinary approach is required to recognize and treat AF appropriately; to limit the catastrophic consequences such as stroke, heart failure, and dementia; and to decrease the burden on the healthcare system. Hospitalization related to AF is the single largest contributor to overall cost of care in managing AF patients. In this study, we examined the trends of AF hospitalizations in the United States and assessed the effects of patient demographics and comorbid diagnoses on in-hospital mortality, length of stay, and total cost of care. Understanding these factors helps us understand the health economics of AF better. There has been a significant increase in AF hospitalizations over the last decade, with a large contribution from patients >65 years of age, especially among those >80 years of age. The overall length of hospital stay has remained unchanged; however, the cost of inpatient care has increased tremendously, from approximately $2.15 billion in 2001 to $3.46 billion in 2010. To the best of our knowledge, this is the first study to assess the trends of AF-related inpatient care at a national level from the actual hospital discharge database. Such data, although they have inherent limitations, tend to provide more accurate financial trajectory of the problem.

CLINICAL PERSPECTIVE

Atrial fibrillation (AF) is one of the most frequently encountered arrhythmias in the hospital. A multidisciplinary approach is required to recognize and treat AF appropriately; to limit the catastrophic consequences such as stroke, heart failure, and dementia; and to decrease the burden on the healthcare system. Hospitalization related to AF is the single largest contributor to overall cost of care in managing AF patients. In this study, we examined the trends of AF hospitalizations in the United States and assessed the effects of patient demographics and comorbid diagnoses on in-hospital mortality, length of stay, and total cost of care. Understanding these factors helps us understand the health economics of AF better. There has been a significant increase in AF hospitalizations over the last decade, with a large contribution from patients >65 years of age, especially among those >80 years of age. The overall length of hospital stay has remained unchanged; however, the cost of inpatient care has increased tremendously, from approximately $2.15 billion in 2001 to $3.46 billion in 2010. To the best of our knowledge, this is the first study to assess the trends of AF-related inpatient care at a national level from the actual hospital discharge database. Such data, although they have inherent limitations, tend to provide more accurate financial trajectory of the problem.


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