



Congestive heart failure-related hospital deaths across the urban-rural continuum in the United States

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ABSTRACT

Congestive heart failure (CHF) is a growing public health problem that affects nearly 6.5 million individuals nationwide. Access to quality outpatient care and disease management programs has been shown to improve disease treatment and prognosis. Rural populations face unique challenges in the availability and accessibility of quality cardiovascular care. In 2018, we conducted a pooled cross-sectional analysis of the Nationwide Inpatient Sample (NIS) for 2009–2014 to examine recent trends in CHF-related hospital deaths in the United States, highlighting urban-rural differences within each census region. We performed a multivariable logistic regression analysis to compare the odds of CHF-related hospital death, by levels of rurality and within each census region. Most CHF-related hospital deaths occurred in the South and Midwest census regions and in large central metropolitan areas. Findings from census region stratified models revealed that non-core residents living within the West (OR 1.47, CI 1.26, 1.71), Midwest (OR 1.30, CI 1.17, 1.44), and South (OR = 1.21, 95% C.I. = 1.12–1.32) had a higher relative risk (but not higher absolute numbers) of experiencing death during a CHF-related hospitalization, compared to patients in large central metropolitan areas. Within each census region, there were also differences in odds of a CHF-related hospital death depending on patient sex, comorbidities, insurance type, median annual income, and year. As efforts to reduce rural health disparities in CHF morbidity continue, more work is needed to understand and test interventions to reduce the risk of death from CHF in noncore areas of the West, Midwest, and South.

1. Introduction

Congestive heart failure (CHF) is a growing and elusive public health problem that affects nearly 6.5 million individuals nationwide (Roger, 2013; Benjamin et al., 2017). Congestive heart failure, otherwise known as heart failure, is a chronic condition that occurs when the heart is unable to pump enough blood to satisfy the needs of the body. Frequently associated with significant morbidity and mortality, CHF is the leading cause of emergency room visits, hospital admissions, and hospital readmissions among persons over age 65 (Hall et al., 2012; Centers for Disease Control and Prevention, 2016; Dharmarajan et al., 2013). Congestive heart failure also imposes a substantial economic burden on the healthcare system, resulting in an estimated 31 billion per year in healthcare costs (Benjamin et al., 2017; Centers for Disease

Control and Prevention, 2016). Despite this, access to quality outpatient disease management programs for CHF has been shown to improve disease prognosis, increase utilization of evidence based therapies, and reduce CHF-related hospital admissions and associated hospital mortality (Atienza et al., 2004). Therefore, The Agency for Healthcare Research and Quality (AHRQ) has identified CHF as an ambulatory care sensitive condition, defined as a condition for which hospital admission and related mortality could be prevented with access to adequate and timely outpatient care (Purdy et al., 2009).

Rural populations face unique challenges in the availability and accessibility of quality health care services. Compared to urban individuals, rural residents have a higher prevalence of cardiovascular disease, and are more likely to be readmitted with CHF complications (Jin et al., 2003). Evidence suggests that rural residents are less likely

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than their urban counterparts to receive regular preventative care and screening services, resulting in fewer medical visits, under diagnosis and suboptimal health outcomes (Casey et al., 2000). A variety of factors contribute to healthcare access challenges among rural populations, including geographic isolation, provider shortages, economic stagnation, and high rates of uninsurance (Bolin et al., 2011; Bolin et al., 2015; Casey et al., 2001). Studies have shown that there are differences in CHF-related hospitalizations, readmissions, and mortality across census regions, racial groups, and low-income populations (Zhang and Watanabe-Galloway, 2008; Ogunniyi et al., 2012; Casper et al., 2010; Akintoye et al., 2017; Liu et al., 2018; Joshi et al., 2004). However, there is limited national-level research comparing rural and urban variations in CHF mortality within each U.S. census region. As a result, it is unclear whether uniform improvements in the burden of CHF mortality have been made across the U.S., or whether place-based disparities persist.

In the present research, we examined recent trends in CHF-related hospital deaths in the United States, highlighting urban-rural differences within each census region. Findings from this study will help to identify geographic areas that are in need of specific interventions to improve access to care and reduce the burden of CHF mortality. This study expands upon previous work with the inclusion of a nationally recognized comprehensive rurality measure (Ingram and Franco, 2012), allowing for a more in-depth analysis of CHF mortality trends across the urban-rural continuum, potentially revealing disparities masked at the national or even regional levels. Findings from this study will help public health practitioners and policy makers identify geographic areas in need of improved access to quality health care.

2. Methods

Data from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) dataset for the years 2009–2014 were utilized for this longitudinal cohort study. The HCUP NIS was established by the Agency for Healthcare Research and Quality (AHRQ) to provide data for national and regional studies focusing on inpatient hospital care in the United States (Houchens et al., 2014). The NIS is the most comprehensive publicly available hospital database, designed to approximate a 20% inpatient sample of all U.S. community hospitals (Houchens et al., 2014).

2.1. Study population and primary outcome

The study population was limited to adult (age ≥ 18 years old) hospital admissions occurring between 2009 and 2014 that had CHF recorded as the principal diagnosis. In the HCUP NIS, the first listed diagnosis is referred to as the principal diagnosis (related to the hospital admission), defined as the condition established to be chiefly responsible for the hospital admission of the patient (Senathirajah et al., 2011). Patient records with a primary diagnosis of CHF were identified using the Clinical Classifications Software (CCS) for International Classification of Diseases, Ninth Revision (ICD-9-CM) diagnosis codes for CHF (CCS code 108), provided by HCUP. The primary outcome assessed for CHF patients was in-hospital death among those hospitalized for CHF. In-hospital death was defined as a death that occurred during a hospitalization for CHF, in which CHF was recorded as the primary diagnosis at admission. However, it is important to note that the same individual could have multiple admissions in the HCUP NIS, therefore the denominator and rates are based on hospital admissions and not individual persons.

We rely on geographic variables - including hospital census region and patient residence level of rurality - as key explanatory measures. Hospital region was identified by census region, including Northeast (reference), Midwest, West, and South. Patient location was identified using the National Center for Health Statistics (NCHS) 2013 Urban-Rural Classification Scheme for Counties (Joshi et al., 2004) that

categorizes patient rurality into 6-levels including: large central metropolitan (reference group), large fringe metropolitan, medium metropolitan, small metropolitan, micropolitan, and non-core areas. Micropolitan and non-core are considered non-metropolitan, whereas the remaining four categories are considered metropolitan areas. Further, according to the Office of Management and Budget, all counties that are not part of metropolitan areas are considered rural, and thus classified accordingly in our analyses (US Office of Management and Budget, 2010).

We also include patient-level characteristics provided by NIS, including patient sex, age, race, insurance type, income, and comorbidities. Patient sex was dummy coded, with males coded as the reference group. Patient age was grouped into five categories, including: 18–44 (reference group), 45–54, 55–64, 65–75, and over 75.

Race and ethnicity variables included White (reference group), Black, Hispanic, Asian or Pacific Islander (P.I.), Native American, and other. In our study sample, we observed a large proportion of missing or incomplete data values for patient race ($N = 91,066$), which might potentially produce misleading, biased, or inaccurate results. To mitigate this issue, we included a missing category for patient race.

We account for insurance type using a primary expected payer measure that includes Medicare, Medicaid, self-pay/uninsured, no charge/other, and private or employer sponsored insurance (reference group). The “no charge/other” insurance category includes charity care, worker's compensation, Civilian Health and Medical Program of the Uniformed Services (CHAMPUS), Title V, and other government programs. Median household income is measured using HCUP's provided quartile classification of the estimated median income of a patient's ZIP Code of residence. The HCUP's income classification provides four median income quartiles, in the following categories: 0–25th percentile (reference), 26th–50th percentile, 51st–75th percentile, and 76th–100th percentile. The bottom quartile (0–25th percentile) indicates the poorest communities.

Patient comorbidities were measured using the Charlson comorbidity index (CCI), a method for classifying comorbid conditions which might alter the risk of mortality in longitudinal studies. Patient comorbidities were identified using information from each patient discharge record, where up to ten ICD-9-CM diagnosis and procedural codes were used to assess comorbidity. The CCI then provides a score accounting for patient comorbidities. Charlson comorbidity scores were divided into 3 groups (0–2, 3–5, and ≥ 6) with higher scores indicating higher comorbidity (Deyo et al., 1992).

2.2. Statistical analysis

All analyses used weighting to obtain national estimates (Houchens et al., 2014). We first generated descriptive statistics for CHF-related hospitalizations, and CHF-related hospital deaths for the years 2009 to 2014. Then, we performed bivariate analysis to measure associations between covariates and CHF-related in-hospital mortality. Subsequently, we performed a general multivariable logistic regression analysis to compare the odds of in-hospital death, by levels of rurality (regardless of region), controlling for potential confounding variables. Cross product terms were incorporated into a subsequent multivariable logistic regression model to evaluate the statistical interaction between rurality and census region. Then, separate region-specific multivariable logistic regressions were performed to further investigate differences in odds of an in-hospital death across the urban-rural continuum within each U.S. census region. All analyses were performed in 2018 using Stata 14 (StataCorp, 2015) statistical software.

2.3. Sensitivity analysis

Given that the race/ethnicity variables in hospitalization data are often questioned, and often contain a large proportion of missing data, we performed a sensitivity analysis by repeating our multivariable

Table 1
Characteristics of congestive heart failure (CHF) related Hospitalizations using the HCUP Nationwide Inpatient Sample for years 2009–2014.*

Variable	CHF Hospitalizations that did not result in death N = 5,397,453	CHF hospitalizations that resulted in death N = 172,982	Total CHF hospitalizations N = 5,570,436
<i>Patient location</i>			
Large Central Metro	27.56 (0.71)	0.78 (0.02)	28.34 (0.07)
Large Fringe Metro	22.51 (0.62)	0.71 (0.02)	23.22 (0.64)
Medium Metro	17.98 (0.63)	0.58 (0.02)	18.56 (0.65)
Small Metro	9.10 (0.40)	0.31 (0.01)	9.411 (0.41)
Micropolitan	11.28 (0.26)	0.40 (0.01)	11.67 (0.27)
Noncore	8.48 (0.02)	0.32 (0.01)	8.80 (0.20)
<i>Census Region</i>			
Northeast	20.03 (0.44)	0.72 (0.02)	20.74 (0.46)
Midwest	22.55 (0.44)	0.70 (0.02)	23.25 (0.45)
South	39.22 (0.57)	1.20 (0.02)	40.43 (0.59)
West	15.10 (0.39)	0.47 (0.01)	15.58 (0.40)
<i>Race/Ethnicity</i>			
White	60.67 (0.52)	2.24 (0.03)	62.92 (0.54)
Black	17.49 (0.37)	0.31 (0.01)	17.80 (0.37)
Hispanic	6.78 (0.23)	0.17 (0.01)	6.94 (0.24)
Asian/Pacific Islander	1.61 (0.07)	0.05 (0.003)	1.66 (0.07)
Native American	0.49 (0.04)	0.01 (0.001)	0.50 (0.04)
Other	2.13 (0.12)	0.07 (0.005)	2.21 (0.12)
Missing	7.72 (0.48)	0.25 (0.01)	7.96 (0.49)
<i>Insurance Coverage</i>			
Commercial/Private	11.32 (0.14)	0.34 (0.01)	11.67 (0.14)
Medicare	72.6 (0.21)	2.48 (0.02)	75.11(0.22)
Medicaid	8.03 (0.14)	0.13 (0.004)	8.16 (0.14)
Uninsured/self-pay	3.01 (0.09)	0.05(0.004)	3.06 (0.09)
No charge/other	1.91 (0.05)	0.10 (0.01)	2.01 (0.05)
<i>Age</i>			
18–44	3.85 (0.05)	0.05 (0.003)	3.91 (0.05)
45–54	8.15 (0.09)	0.10 (0.004)	8.26 (0.09)
55–64	14.71 (0.09)	0.25 (0.005)	14.96 (0.10)
65–74	20.37 (0.07)	0.51 (0.01)	20.88 (0.07)
75+	49.81 (0.23)	2.18 (0.02)	51.99 (0.24)
<i>Sex</i>			
Male	48.70 (0.09)	1.56 (0.01)	50.25 (0.09)
Female	48.20 (0.02)	1.55 (0.01)	49.75 (0.09)
<i>Median Income</i>			
0–25th percentile (poorest)	32.06 (0.44)	0.93 (0.02)	33.0 (0.45)
26th–50th percentile	25.73 (0.32)	0.82 (0.01)	26.55 (0.34)
51st–75th percentile	21.94 (0.30)	0.72 (0.01)	22.67 (0.31)
76th–100th percentile (wealthiest)	0.42)	0.64 (0.02)	17.80 (0.44)
<i>Charlson CMI</i>			
0–2	37.39 (0.15)	1.07 (0.01)	38.46 (0.15)
3–5	50.84 (0.11)	1.69 (0.02)	52.53 (0.11)
6+	8.67 (0.07)	0.35 (0.01)	9.01 (0.07)
<i>Year</i>			
2009	16.98 (0.66)	0.57 (0.02)	17.55 (0.69)
2010	16.80 (0.65)	0.55 (0.02)	17.35 (0.67)
2011	16.83 (0.65)	0.55 (0.02)	17.38 (0.67)
2012	15.23 (0.35)	0.49 (0.01)	15.72 (0.36)
2013	15.35 (0.35)	0.48 (0.01)	15.83 (0.36)
2014	15.70 (0.35)	0.47 (0.01)	16.18 (0.36)

Note. All values were weighted to produce national estimates.

* Values are given as percent (standard error) of total CHF hospitalizations.

logistic regression to compare the odds of in-hospital death, by levels of rurality (regardless of region) using only data where race/ethnicity was not missing.

3. Results

From 2009 to 2014, there were an estimated 5.57 million hospitalizations with a primary diagnosis of CHF, of which an estimated 172,972 resulted in death during hospitalization (Table 1). The greatest frequency of CHF in-hospital deaths occurred in 2009 (0.57% of all CHF hospitalizations), and the fewest proportion of deaths occurred in 2014 (0.47% of all CHF hospitalizations). Among census regions, the South experienced the greatest frequency of in-hospital deaths (1.20% of all CHF hospitalizations), and the lowest frequency of in-hospital deaths occurred in the West census region (0.47% of all CHF hospitalizations). Additionally, the majority of in-hospital deaths occurred among residents of large central metropolitan areas (0.78% of all CHF hospitalizations), and the lowest proportion of in-hospital deaths occurred among residents of small metropolitan areas (0.31% of all CHF hospitalizations). Among racial groups, in-hospital death associated with CHF occurred most often white patients (2.24% of all CHF hospitalizations), followed by Black patients (0.31% of all CHF hospitalizations). In-hospital deaths occurred more frequently among older patients, with of the majority of CHF-related-hospital deaths occurring in patients over age 75. Accordingly, most in-hospital deaths occurred among individuals insured through Medicare (2.48% of all CHF hospitalizations). Furthermore, most (0.93% of all CHF hospitalizations) CHF in-hospital deaths occurred among patients in the 0–25th (poorest) median income percentile. Heart failure-related hospital deaths were also most common among individuals diagnosed with 3–5 comorbidities (1.69% of all CHF hospitalizations).

Results from the bivariate and multivariable logistic regression models are displayed in Table 2. The bivariate logistic regression models revealed significant associations between a number of the independent variables and death during a CHF-related hospitalization. Results from our multivariable logistic regression model illustrate differences in odds of in-hospital death across the rural urban continuum, regardless of census region. Notably, CHF patients hospitalized in small metropolitan (OR: 1.12; 95% C.I. = 1.06–1.18), micropolitan (OR: 1.13; 95% C.I. = 1.08–1.19) and noncore (OR: 1.22; 95% C.I. = 1.16–1.29) areas had significantly higher odds of in-hospital death compared to patients living in large central metropolitan areas. Compared to patients hospitalized in the Midwest, patients in the Northeast were 17% more likely to die during a hospitalization for CHF (OR: 1.17; 95% C.I. = 1.11–1.23).

Looking at additional characteristics, old age was the strongest independent predictor of in-hospital death, with patients over age 75 displaying more than triple the odds (OR:3.07; 95% C.I. = 2.77–3.40) of in-hospital death, relative to patients in the 18–44 age group. Regarding race, compared to white individuals, black patients experienced the lowest odds of in-hospital mortality associated with CHF (OR = 0.69, 95% C.I = 0.65–0.73) patients, followed by Hispanics (OR = 0.79, 95% C.I = 0.75–0.84). When we conducted a sensitivity analysis excluding observations with missing race variables (see Appendix A), the estimated odds of among racial/ethnic groups changed minimally (if at all): black patients continued to have the lowest odds of CHF in-hospital mortality associated with CHF (OR = 0.67, 95% C.I = 0.64–0.70) patients, followed by Hispanics (OR = 0.79, 95% C.I = 0.75–0.84), relative to white patients.

Patients on Medicare (OR = 0.69, 95% C.I = 0.65–0.73), Medicaid (OR = 0.78, 95% C.I = 0.72–0.84), and uninsured individuals (OR = 0.82, 95% C.I = 0.69–0.97), had lower odds of in-hospital death, while those covered by some ‘other’ type of government insurance (OR: 1.79; 95% C.I. = 1.58–2.02) had higher odds of in-

Table 2
Unadjusted and adjusted odds of in-hospital mortality among congestive heart failure (CHF) hospitalizations using the HCUP Nationwide Inpatient Sample for years 2009–2014.

Variable	Unadjusted Odds Ratio (95% C.I.)	Adjusted Odds Ratio (95% C.I.)
<i>Patient Location</i>		
Large Central Metro	Reference	Reference
Large Fringe Metro	1.11 (1.06–1.16) ^{***}	0.94 (0.90–0.98)
Medium Metro	1.13 (1.08–1.19) ^{***}	1.01 (0.97–1.06)
Small Metro	1.21 (1.15–1.28) ^{***}	1.12 (1.06–1.18) ^{***}
Micropolitan	1.24 (1.18–1.31) ^{***}	1.13 (1.08–1.19) ^{***}
Noncore	1.32 (1.26–1.40) ^{***}	1.22 (1.16–1.29) ^{***}
<i>Census Region</i>		
Northeast	1.15 (1.09–1.21) ^{***}	1.17 (1.11–1.23) ^{***}
Midwest	Reference	Reference
South	0.99 (0.95–1.04)	1.08 (1.03–1.22) ^{***}
West	1.01 (0.96–1.07)	1.05 (1.01–1.11) [*]
<i>Race/Ethnicity</i>		
White	Reference	Reference
Black	0.48 (0.46–0.50) ^{***}	0.68 (0.65–0.71) ^{***}
Hispanic	0.67 (0.63–0.71) ^{***}	0.79 (0.75–0.84) ^{***}
Asian/P.I.	0.85 (0.78–0.93) ^{***}	0.92 (0.84–1.01)
Native American	0.70 (0.58–0.83) ^{***}	0.82 (0.68–0.97) [*]
Other	0.90 (0.83–0.97) [*]	1.01 (0.93–1.10)
Missing	0.84 (0.79–0.90) ^{***}	0.92 (0.87–0.98) ^{***}
<i>Insurance Coverage</i>		
Private	Reference	Reference
Medicare	1.13 (1.08–1.19) ^{***}	0.69 (0.65–0.73) ^{***}
Medicaid	0.52 (0.48–0.56) ^{***}	0.78 (0.72–0.84) ^{***}
Uninsured/self-pay	0.54 (0.46–0.64) ^{***}	0.84 (0.70–0.99) ^{***}
Other	1.74 (1.54–1.97) ^{***}	1.79 (1.58–2.02) ^{***}
<i>Age</i>		
18–44	Reference	
45–54	0.90 (0.92–1.02) [*]	0.86 (0.77–0.95) ^{**}
55–64	1.20 (1.10–1.32) ^{***}	1.07 (0.98–1.18)
65–74	1.78 (1.63–1.95) ^{***}	1.74 (1.57–1.92) ^{***}
75+	3.09 (2.83–3.38) ^{***}	3.07 (2.77–3.40) ^{***}
<i>Sex</i>		
Female	Reference	Reference
Male	0.99 (0.97–1.02)	1.08 (1.05–1.10) ^{***}
<i>Median Income</i>		
0–25th percentile (poorest)	Reference	Reference
26th–50th percentile	1.10 (1.07–1.14) ^{***}	0.98 (0.95–1.02)
51st–75th percentile	1.13 (1.10–1.17) ^{***}	1.02 (0.98–1.05)
76th–100th percentile (wealthiest)	1.28 (1.24–1.33) ^{***}	1.10 (1.05–1.14) ^{***}
<i>Charlson CMI</i>		
0–2	Reference	Reference
3–5	1.16 (1.13–1.19) ^{***}	1.18 (1.15–1.21) ^{***}
6+	1.40 (1.35–1.46) ^{***}	1.49 (1.44–1.55) ^{***}
<i>Year</i>		
2009	Reference	Reference
2010	0.97 (0.92–1.02)	0.98 (0.93–1.03)
2011	0.96 (0.91–1.02)	0.96 (0.91–1.01)
2012	0.95 (0.92–0.99) [*]	0.94 (0.90–0.99)
2013	0.92 (0.88–0.97) ^{**}	0.93 (0.88–0.97) ^{**}
2014	0.89 (0.85–0.94) ^{***}	0.90 (0.86–0.95) ^{***}

* p < 0.05.

** p < 0.01.

*** p < 0.001.

hospital death, compared to those privately insured. Furthermore, patients who were hospitalized with six or more comorbidities (OR: 1.49; 95% C.I. = 1.44–1.55), were male (OR: 1.08; 95% C.I. = 1.05–1.10), and in the highest median income quartile had greater odds of in-hospital death (OR:1.10; 95% C.I. = 1.05–1.14).

To examine potential differences in CHF-related hospital mortality across regions in urban–rural classification, we performed a subsequent multivariable logistic regression that included a region-by-rurality interaction term (Appendix B). Results indicated a significant interaction between region and rurality. In particular, results indicated that odds of CHF in-hospital death were higher in micropolitan and noncore areas of the South, Midwest, and West, compared to micropolitan and noncore areas in the Northeast.

Because we found a significant interaction between census region and levels of rurality, additional separate multivariable logistic regressions were performed to further examine factors contributing to urban–rural differences in odds of CHF in-hospital death within each census region (Table 3). In the Midwest, the odds of in-hospital CHF-associated death increased as areas became more rural, with the highest odds occurring in noncore areas (OR = 1.30, 95% C.I. = 1.17–1.44), followed by micropolitan (OR = 1.20, 95% C.I. = 1.09–1.33), and small metropolitan areas (OR = 1.19, 95% C.I. = 1.07–1.32). In the South, odds of in-hospital death from CHF were also highest among noncore, or rural residents (OR = 1.21, 95% C.I. = 1.12–1.32), followed by micropolitan (OR = 1.14, 95% C.I. = 1.05–1.23) and small metropolitan (OR = 1.10, 95% C.I. = 1.01–1.20). Similar to the Midwest and South, noncore residents of the West had the highest likelihood of in-hospital death (OR = 1.47, 95% C.I. = 1.26–1.71), followed by micropolitan (OR = 1.25, 95% C.I. = 1.10–1.42) areas. Unlike other regions, odds of death in the Northeast did not increase as areas became less urban and more rural.

Across all regions, Black patients had the lowest odds of an in-hospital CHF associated death. Within the Northeast, Midwest, and South, patients covered by some ‘other’ type of government insurance had the highest odds of in-hospital death (OR = 1.63, 95% C.I. = 1.22–2.18; OR = 2.11, 95% C.I. = 1.62–2.76, OR = 2.00, 95% C.I. = 1.67–2.39). In all regions, patients covered through Medicare had lower odds of death compared to those on private insurance. While odds of CHF in-hospital death were lowest among uninsured patients in the Northeast (OR = 0.72, 95% C.I. = 0.52–0.99) and West (OR = 0.68, 95% C.I. = 0.52–0.90), odds of death among uninsured individuals in the Midwest and South did not significantly differ from those on private insurance.

There were also regional differences in odds of an in-hospital CHF-related hospital deaths depending on patient sex, number of comorbidities, median annual income, and year. For example, male patients displayed significantly higher odds of death within the South (OR = 1.12, 95% C.I. = 1.08–1.16), Midwest (OR = 1.07, 95% C.I. = 1.03–1.12), and West (OR = 1.06, 95% C.I. = 1.01–1.12), but not the Northeast. Across all regions, patients with six or more comorbidities displayed the highest odds of death during a CHF-related hospitalization. Compared to patients in the lowest income quartile, those in the highest income quartile were significantly more likely to experience death during a CHF-related hospitalization in the South (OR = 1.15, 95% C.I. = 1.07–1.24), Northeast (OR = 1.13, 95% C.I. = 1.03–1.23), and West (OR = 1.11, 95% C.I. = 1.01–1.22), but not the Midwest. Patients residing in the U.S. South census region experienced a 12% decrease in odds in 2014, compared to 2009 (OR = 0.88, 95% C.I. = 0.82–0.95). Patients hospitalized in the Northeast and Midwest also experienced decreases in odds of in-hospital death in 2014, compared to 2009 (OR = 0.89, 95% C.I. = 0.80–0.99), and (OR = 0.89, 95% C.I. = 0.80–0.99), respectively. However, in the West, odds of mortality did not significantly change from year to year.

4. Discussion

In this study, we examined trends in CHF-related in-hospital death between 2009 and 2014 in the United States, highlighting differences

Table 3

Odds of in-hospital mortality among congestive heart failure (CHF) hospitalizations within four U.S. census regions using the HCUP Nationwide Inpatient Sample for years 2009–2014.

Variable	Northeast Odds Ratio (95% C.I.)	Midwest Odds Ratio (95% C.I.)	South Odds Ratio (95% C.I.)	West Odds Ratio (95% C.I.)
<i>Patient Location</i>				
Large Central Metro	Reference	Reference	Reference	Reference
Large Fringe Metro	0.81 (0.74–0.89)***	1.03 (0.94–1.13)	0.9 (0.84–0.97)**	1.06 (0.96–1.17)
Medium Metro	0.84 (0.76–0.93)**	1.08 (0.98–1.20)	1.02 (0.95–1.11)	1.09 (0.99–1.20)
Small Metro	1.06 (0.94–1.20)	1.19 (1.07–1.32)**	1.10 (1.01–1.20)*	1.14 (0.99–1.31)
Micropolitan	0.96 (0.85–1.07)	1.20 (1.09–1.33)**	1.14 (1.05–1.23)**	1.25 (1.10–1.42)**
Noncore	0.93 (0.80–1.09)	1.30 (1.17–1.44)**	1.21 (1.12–1.32)**	1.47 (1.26–1.71)**
<i>Race/Ethnicity</i>				
White	Reference	Reference	Reference	Reference
Black	0.61 (0.56–0.68)***	0.63 (0.57–0.71)***	0.72 (0.68–0.76)***	0.64 (0.56–0.73)***
Hispanic	0.78 (0.69–0.89)***	0.78 (0.60–1.01)	0.83 (0.76–0.90)***	0.75 (0.68–0.83)***
Asian/P.I.	0.94 (0.75–1.19)	0.83 (0.60–1.14)	0.80 (0.63–1.01)	0.96 (0.85–1.07)
Native American	1.07 (0.52–2.19)	0.93 (0.64–1.35)	0.73 (0.55–0.98)*	0.77 (0.56–1.06)
Other	0.93 (0.80–1.07)	1.08 (0.86–1.35)	1.03 (0.90–1.18)	0.99 (0.80–1.21)
Missing	1.37 (1.08–1.74)*	0.87 (0.80–0.95)**	0.93 (0.85–1.02)	1.06 (0.92–1.24)
<i>Insurance Coverage</i>				
Private	Reference	Reference	Reference	Reference
Medicare	0.74 (0.63–0.83)***	0.60 (0.53–0.68)***	0.65 (0.60–0.71)***	0.89 (0.80–0.99)*
Medicaid	0.69 (0.57–0.83)***	0.70 (0.60–0.83)***	0.81 (0.71–0.91)**	0.90 (0.78–1.04)
Uninsured/self-pay	0.72 (0.52–0.99)*	0.85 (0.65–1.12)	0.90 (0.68–1.21)	0.68 (0.52–0.90)**
Other	1.63 (1.22–2.18)**	2.11 (1.62–2.76)***	2.00 (1.67–2.39)***	0.84 (0.66–1.08)
<i>Age</i>				
18–44	Reference	Reference	Reference	Reference
45–54	0.91 (0.68–1.21)	0.94 (0.75–1.17)	0.86 (0.74–0.99)*	0.78 (0.62–0.98)*
55–64	1.29 (0.99–1.70)	1.09 (0.89–1.34)	1.13 (0.98–1.29)	0.83 (0.68–1.03)
65–74	1.81 (1.36–2.43)***	1.87 (1.51–2.31)***	1.99 (1.70–2.33)***	1.14 (0.92–1.40)
75+	3.33 (2.45–4.54)***	3.42 (2.75–4.25)***	3.42 (2.93–4.00)***	1.92 (1.55–2.38)***
<i>Sex</i>				
Female	Reference	Reference	Reference	Reference
Male	1.01 (0.97–1.06)	1.07 (1.03–1.12)**	1.12 (1.08–1.16)***	1.06 (1.01–1.12)*
<i>Median Income</i>				
0–25th percentile (poorest)	Reference	Reference	Reference	Reference
26th–50th percentile	0.97 (0.89–1.06)	0.97 (0.91–1.03)	0.98 (0.93–1.03)	1.05 (0.96–1.15)
51st–75th percentile	1.05 (0.96–1.14)	0.97 (0.91–1.05)	1.03 (0.97–1.10)	1.01 (0.92–1.11)
76th–100th percentile (wealthiest)	1.13 (1.03–1.23)**	1.02 (0.93–1.12)	1.15 (1.07–1.24)***	1.11 (1.01–1.22)*
<i>Charlson CMI</i>				
0–2	Reference	Reference	Reference	Reference
3–5	1.21 (1.14–1.28)***	1.15 (1.10–1.22)***	1.15 (1.10–1.19)***	1.30 (1.22–1.39)***
6+	1.57 (1.43–1.72)***	1.43 (1.31–1.55)***	1.43 (1.34–1.52)***	1.68 (1.53–1.82)***
<i>Year</i>				
2009	Reference	Reference	Reference	Reference
2010	1.04 (0.94–1.15)	0.92 (0.83–1.03)	1.01 (0.93–1.08)	0.93 (0.81–1.06)
2011	0.97 (0.86–1.10)	0.94 (0.84–1.05)	0.98 (0.91–1.07)	0.90 (0.79–1.03)
2012	0.96 (0.87–1.06)	0.97 (0.88–1.07)	0.93 (0.87–1.00)	0.92 (0.81–1.04)
2013	0.93 (0.84–1.04)	0.91 (0.82–1.01)	0.90 (0.84–0.98)*	0.99 (0.88–1.12)
2014	0.89 (0.80–0.99)*	0.89 (0.80–0.99)*	0.88 (0.82–0.95)**	0.95 (0.84–1.08)

* p < 0.05.

** p < 0.01.

*** p < 0.001.

within each census region and across the urban–rural continuum. Overall, we found that despite significant medical advances in CHF treatment and management in recent years, substantive place-based disparities in the odds of CHF-related hospital mortality persist. Specifically, our multivariable logistic regression analyses revealed that compared to large central metropolitan areas, CHF-related hospital admissions from small metropolitan, micropolitan, and noncore residents were more likely to result in death, even after controlling for patient demographics, census region, and comorbidities. Previous studies on regional variation in CHF mortality suggest that CHF mortality

is highest in the Northeast and lowest in the Midwest (Joshi et al., 2004). However, our regional analyses revealed that the burden of CHF is especially pronounced for micropolitan and noncore residents of the Midwest, South, and West, and we also observe an absence of rural versus urban disparities in the Northeast census region. These regional differences persisted even after controlling for patient age, race/ethnicity, sex, insurance type, year, comorbidities, and median annual income.

Several factors might put rural residents at higher risk of death from CHF than urban residents. For example, rural populations tend to be

older, have higher rates of poverty, and lower levels of education, compared to their urban counterparts (Bolin et al., 2011; Barker et al., 2013). Rural Americans also have higher rates of tobacco use, physical inactivity, obesity, diabetes, and hypertension than urban residents (Bolin et al., 2011; Bolin et al., 2015; Befort et al., 2012; Vitolins et al., 2007; Doescher et al., 2006; Bell et al., 2009). Furthermore, rural populations often face significant challenges accessing quality health care due to geographic isolation, limited availability of providers, inadequate transportation, or lack of health insurance (Barker et al., 2013; Bolin et al., 2011; Bolin et al., 2015; Casey et al., 2001). Limited access to health services, including primary care and disease self-management programs adversely impacts CHF treatment and prognosis, potentially leading to increased CHF mortality among rural residents (Casey et al., 2000; Bolin et al., 2011; Bolin et al., 2015; Casey et al., 2001).

Geographic variations in CHF-related in hospital mortality could also indicate that rural residents in the Midwest, West, and South receive lower quality CHF-related care than their urban counterparts. In fact, results from prior studies suggests that heart failure patients tend to be more effectively managed in the urban hospital setting compared to hospitals located in rural areas (Lutfiyya et al., 2007; Yuan et al., 2000; Baker et al., 1999). For example, one study revealed that urban acute care hospitals were more likely to provide smoking-cessation counseling for heart failure patients, compared to rural hospitals (Lutfiyya et al., 2007). Rural medical institutions also have limited technological and clinical resources and employ fewer cardiovascular specialists than urban hospitals (Casey et al., 2000; Bolin et al., 2011). Also, given the well documented association between hospital volume and quality of care, rural hospitals likely see a much lower volume of heart failure patients, and as a result could be less proficient at treating these patients than their urban counterparts (Wagnild et al., 2004).

Consistent with previous study findings, we found that patients who are female, under age 65, or African American/Black had decreased odds of in hospital CHF mortality across regions (Akintoye et al., 2017; Joshi et al., 2004). However, our analysis revealed counter-intuitive associations between CHF-related hospital mortality and income and insurance type. The unexpected association between CHF-related hospital mortality and median household income could be the result of the operationalization of this measure which relies on ZIP Code-level income as opposed to patient income. However, further explanations of counter-intuitive findings are beyond the scope of this study. Thus, future research should continue to explore associations between patient income, insurance type, and risk of CHF-related hospital mortality.

5. Limitations

As with any study, there are limitations of this analysis. First, the primary outcome variable for this study was in-hospital death. Thus, deaths associated with CHF occurring outside of a hospital setting were not taken into consideration.

Moreover, because CHF is a syndrome and not a disease, its diagnosis is challenging, and admittedly standardized diagnostic criteria may be inconsistently applied (Remes et al., 1991; Cainzos-Achirica

Appendix A

See [Table A1](#)

et al., 2018). For example, the complex syndrome of CHF has many different clinical presentations. Variations in the presentation of CHF stem from its diverse causes, varying degrees of cardiac dysfunction, and wide assortment of signs and symptoms. Furthermore, the primary symptoms of CHF (including fatigue, shortness of breath, or swelling in legs and feet) – are also present in a variety of other medical conditions common in older adults (Cainzos-Achirica et al., 2018). Because there is no physical sign, imaging test, or blood assay that is definitive for the diagnosis of CHF, an accurate identification of CHF cases can be more challenging than for other conditions (Remes et al., 1991; Cainzos-Achirica et al., 2018). As a result, all cases of CHF may not be fully captured by the disease coding system used in this analysis, which could impact data quality. To mediate this issue, we utilized the Clinical Classifications Software (provided by HCUP) to identify CHF cases using a series of ICD-9 codes that have high specificity and positive predictive values for CHF (Saczynski et al., 2012).

Lastly, because the HCUP sample consists of hospitalizations, estimates could be biased due to variations in the severity of CHF between regions and levels of urbanization. We were also unable to identify readmissions for CHF, as the unit of our analysis was at the visit level, so a portion of CHF hospitalizations included in this study could represent a repeated admission from the same patient.

6. Conclusion

This study provides insight into the extent that CHF-related in-hospital mortality varies across six levels of urbanization and four census regions. Despite various policy efforts to improve health services in rural areas, our results indicate a need for continued policy attention to improve the quality of care provided to rural CHF patients. Many of the risk factors for CHF, such as diabetes, obesity, and hypertension, are largely preventable with a combination of access to quality medical care and living environments that promote healthy lifestyle choices. Findings from this study can be used by public health professionals and policy makers to identify regions that are in particular need of improved access to quality health care. More research is needed to further investigate the interplay of region-specific social, environmental, economic and health care system-associated factors contributing to the increased burden of CHF mortality in rural areas so that all Americans have equal access to high quality cardiovascular care.

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Table A1

Sensitivity analysis-adjusted odds of CHF in-hospital death (contains only non-missing race data) using the HCUP National Inpatient Sample for years 2009–2014.

Variable	Odds Ratio (95% C.I.)
<i>Urban/rural location</i>	
Large Central Metro	1.00 (Reference)
Large Fringe Metro	0.93 (0.89–0.98) ^{***}
Medium Metro	0.99 (0.95–0.95)
Small Metro	1.11 (1.05–0.97) ^{***}
Micropolitan	1.12 (1.06–0.98) ^{***}
Noncore	1.21 (1.15–0.98) ^{***}
<i>Region</i>	
Northeast	1.16 (1.10–1.22) ^{***}
Midwest	1.00 (Reference)
South	1.06 (1.02–1.11) ^{**}
West	1.03 (0.98–1.09)
<i>Race/Ethnicity</i>	
White	1.00 (Reference)
Black	0.67 (0.64–0.7) ^{***}
Hispanic	0.79 (0.75–0.84) ^{***}
Asian/PI	0.92 (0.84–1.01)
Native American	0.81 (0.68–0.97) [*]
Other	1.01 (0.93–1.10)
<i>Insurance</i>	
Private	1.00 (Reference)
Medicare	0.68 (0.65–0.73)
Medicaid	0.78 (0.72–0.84)
Self-pay	0.84 (0.7–1.01)
No charge & Other	1.76 (1.56–2.00) ^{***}
<i>Age</i>	
18–44	1.00 (Reference)
45–54	0.85 (0.77–0.95) ^{***}
55–64	1.07 (0.97–0.2.17)
65–74	1.72 (1.55–0.91) ^{***}
75 +	3.04 (2.73–0.38) ^{***}
<i>Sex</i>	
Male	1.08 (1.06–1.11) ^{***}
Female	1.00 (Reference)
<i>Median Income</i>	
0–25th percentile (poorest)	1.00 (Reference)
26th–50th percentile	0.98 (0.95–1.02)
51st–75th percentile	1.01 (0.97–1.05)
76th–100th percentile (wealthiest)	1.09 (1.04–1.14) ^{***}
<i>Charleston CMI</i>	
0–2	1.00 (Reference)
3–5	1.19 (1.16–1.22) ^{***}
6 +	1.51 (1.45–1.57) ^{***}
<i>Year</i>	
2009	1.00 (Reference)
2010	0.99 (0.95–1.05)
2011	0.96 (0.91–1.02)
2012	0.94 (0.89–0.99) [*]
2013	0.93 (0.88–0.98) ^{**}
2014	0.90 (0.85–0.94) ^{***}

* p < 0.05.

** p < 0.01.

*** p < 0.001.

Appendix B

See [Table B1](#)

Table B1
Adjusted Odds of CHF-Related Hospital Deaths (with patient location and census region interaction) using the HCUP National Inpatient Sample for years 2009–2014.

Variable	Odds Ratio (95% C.I.)
<i>Patient Location</i>	
Large Central Metro	1.00 (reference)
Large Fringe Metro	0.84 (0.77–0.91)***
Medium Metro	0.87 (0.79–0.96)*
Small Metro	1.09 (0.97–1.23)
Micropolitan	0.98 (0.88–1.10)
Noncore	0.96 (0.82–1.11)
<i>Census Region</i>	
Northeast	1.00 (reference)
Midwest	0.73 (0.66–0.81)***
South	0.86 (0.79–0.94)***
West	0.78 (0.72–0.86)***
<i>Patient Location#Census Region</i>	
Large Fringe#Northeast	1.00 (reference)
Large Fringe#Midwest	1.22 (1.08–1.38)***
Large Fringe#South	1.07 (0.96–1.20)
Large Fringe#West	1.25 (1.10–1.43)***
Medium Metro#Northeast	1.00 (reference)
Medium Metro#Midwest	1.25 (1.08–1.45)***
Medium Metro#South	1.16 (1.02–1.31)*
Medium Metro#West	1.26 (1.09–1.44)***
Small Metro#Northeast	1.00 (reference)
Small Metro#Midwest	1.11 (0.95–1.30)
Small Metro#South	0.99 (0.86–1.15)
Small Metro#West	1.05 (0.87–1.27)
Micropolitan#Northeast	1.00 (reference)
Micropolitan#Midwest	1.26 (1.08–1.46)***
Micropolitan#South	1.13 (0.98–1.30)
Micropolitan#West	1.27 (1.08–1.51)*
Noncore#Northeast	1.00 (reference)
Noncore#Midwest	1.41 (1.17–1.68)***
Noncore#South	1.24 (1.05–1.47)*
Noncore#West	1.55 (1.27–1.91)***
<i>Race/Ethnicity</i>	
White	1.00 (reference)
Black	0.67 (0.65–0.70)***
Hispanic	0.79 (0.75–0.83)***
Asian/P.I.	0.93 (0.85–1.01)
Native American	0.80 (0.67–0.96)*
Other	0.99 (0.92–1.09)
Missing	0.92 (0.86–0.97)*
<i>Insurance Coverage</i>	
Private	0.69 (0.65–0.73)***
Medicare	0.78 (0.72–0.84)***
Medicaid	1.00 (reference)
Uninsured/self-pay	0.83 (0.7–0.99)*
Other	1.79 (1.58–2.03)***
<i>Age</i>	
18–44	1.00 (reference)
45–54	0.86 (0.77–0.95)***
55–64	1.07 (0.98–1.18)
65–74	1.74 (1.57–1.92)***
75+	3.06 (2.76–3.39)***
<i>Sex</i>	
Female	1.00 (reference)
Male	1.08 (1.05–1.10)***
<i>Charlson CMI</i>	
0–2	1.00 (reference)
3–5	1.18 (1.15–1.21)***
6+	1.50 (1.44–1.56)***
<i>Median Income</i>	
0–25th percentile (poorest)	1.00 (reference)
26th–50th percentile	0.99 (0.96–1.02)
51st–75th percentile	1.02 (0.98–1.06)
76th–100th percentile (wealthiest)	1.11 (1.06–1.16)***
<i>Year</i>	
2009	1.00 (reference)

Table B1 (continued)

Variable	Odds Ratio (95% C.I.)
2010	0.98 (0.93–1.03)
2011	0.96 (0.91–1.01)
2012	0.94 (0.90–0.99)*
2013	0.93 (0.88–0.97)***
2014	0.90 (0.86–0.94)***

* $p < 0.05$, ** $p < 0.01$.*** $p < 0.001$.

References

- Akintoye, E., Briasoulis, A., Egbe, A., Adegba, O., Sheikh, M., Singh, M., Kushwaha, S., 2017. Regional variation in mortality, length of stay, cost, and discharge disposition among patients admitted for heart failure in the United States. *Am. J. Cardiol.* 120 (5), 817–824.
- Atienza, F., Anguita, M., Martinez-Alzamora, N., Osca, J., Ojeda, S., Almenar, L., de Velasco, J.A., 2004. Multicenter randomized trial of a comprehensive hospital discharge and outpatient heart failure management program. *Eur. J. Heart Fail.* 6 (5), 643–652.
- Baker, D.W., Fitzgerald, D., Moore, C.L., 1999. Quality of care for Medicare patients hospitalized with heart failure in rural Georgia. *South. Med. J.* 92 (8), 782–789.
- Barker, A. R., Londeree, J. K., McBride, T. D., Kemper, L. M., & Mueller, K. (2013). The uninsured: an analysis by income and geography. *Rural Policy Brief*, (2013 6), 1–4.
- Befort, C.A., Nazir, N., Perri, M.G., 2012. Prevalence of obesity among adults from rural and urban areas of the United States: findings from NHANES (2005–2008). *J. Rural Health* 28 (4), 392–397.
- Bell, R.A., Arcury, T.A., Chen, H., Anderson, A.M., Savoca, M.R., Kohrman, T., Quandt, S.A., 2009. Use of tobacco products among rural older adults: prevalence of ever use and cumulative lifetime use. *Addict. Behav.* 34 (8), 662–667.
- Benjamin, E. J., Blaha, M. J., Chiuve, S. E., Cushman, M., Das, S. R., Deo, R., American Heart Association Statistics Committee and Stroke Statistics Subcommittee. (2017). Heart disease and stroke statistics-2017 update: A report from the American Heart Association. *Circulation*, 135(10), e146–e603. doi:10.1161/CIR.0000000000000485.
- Bolin, J.N., Bellamy, G.R., Ferdinand, A.O., Vuong, A.M., Kash, B.A., Schulze, A., Helduser, J.W., 2015. Rural healthy people 2020: new decade, same challenges. *J. Rural Health* 31 (3), 326–333.
- Bolin, J. N., Bellamy, G., Ferdinand, A. O., Kash, B. A., & Helduser, J. W. (2011). Rural healthy people 2020. College Station, TX: Texas A&M Health Science Center School of Public Health, Southwest Rural Health Research Center.
- Cainzos-Achirica, M., Rebordosa, C., Vela, E., Cleries, M., Matsushita, K., Plana, E., Garcia-Rodriguez, L.A., 2018. Challenges of evaluating chronic heart failure and acute heart failure events in research studies using large health care databases. *Am. Heart J.* 202, 76–83.
- Casey, M., Call, K.T., Klingner, J., 2000. The Influence of Rural Residence on the Use of Preventive Health Care Services. Division of Health Services Research and Policy, School of Public Health, University of Minnesota. Citeseer.
- Casey, M.M., Call, K.T., Klingner, J.M., 2001. Are rural residents less likely to obtain recommended preventive healthcare services? *Am. J. Prev. Med.* 21 (3), 182–188.
- Casper, M., Nwaise, I., Croft, J.B., Hong, Y., Fang, J., Greer, S., 2010. Geographic disparities in heart failure hospitalization rates among Medicare beneficiaries. *J. Am. Coll. Cardiol.* 55 (4), 294–299.
- Centers for Disease Control and Prevention. Heart failure fact sheet. 2016. URL: http://www.cdc.gov/dhbsp/data/statistics/fact_sheets/fs_heart_failure.htm [accessed 2017-09-27][WebCite Cache ID 6tn9Eolnz]. 2017.
- Deyo, R.A., Cherkin, D.C., Ciol, M.A., 1992. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J. Clin. Epidemiol.* 45 (6), 613–619.
- Dharmarajan, K., Hsieh, A.F., Lin, Z., Bueno, H., Ross, J.S., Horwitz, L.I., Drye, E.E., 2013. Diagnoses and timing of 30-day readmissions after hospitalization for heart failure, acute myocardial infarction, or pneumonia. *JAMA* 309 (4), 355–363.
- Doescher, M.P., Jackson, J.E., Jerant, A., Gary Hart, L., 2006. Prevalence and trends in smoking: a national rural study. *J. Rural Health* 22 (2), 112–118.
- Hall, M.J., Levant, S., DeFrances, C.J., 2012. Hospitalization for congestive heart failure; United States, 2000–2010. *NCHS Data Brief* 108, 1–8.
- Houchens, R.L., Ross, D.N., Elixhauser, A., Jiang, J., 2014. Nationwide Inpatient Sample Redesign Final Report. Agency for Healthcare Research and Quality, Rockville, MD.
- Ingram, D.D., Franco, S.J. (2012). NCHS urban-rural classification scheme for counties. *Vital and Health Statistics. Series 2, Data Evaluation and Methods Research*, (Vol. 154), pp. 1–65.
- Jin, Y., Quan, H., Cujec, B., Johnson, D., 2003. Rural and urban outcomes after hospitalization for congestive heart failure in Alberta, Canada. *J. Cardiac Failure* 9 (4), 278–285.
- Joshi, A.V., D'Souza, A.O., Madhavan, S.S., 2004. Differences in hospital length-of-stay, charges, and mortality in congestive heart failure patients. *Congestive Heart Failure* 10 (2), 76–84.
- Liu, L., Yin, X., Chen, M., Jia, H., Eisen, H.J., Hofman, A., 2018. Geographic variation in heart failure mortality and its association with hypertension, Diabetes, and Behavioral-related risk Factors in 1,723 counties of the United States. *Front. Public Health* 6, 132.
- Lutfiyya, M.N., Bhat, D.K., Gandhi, S.R., Nguyen, C., Weidenbacher-Hoper, V.L., Lipsky, M.S., 2007. A comparison of quality of care indicators in urban acute care hospitals and rural critical access hospitals in the United States. *Int. J. Qual. Health Care* 19 (3), 141–149.
- Ogunniyi, M.O., Holt, J.B., Croft, J.B., Nwaise, I.A., Giles, W.H., Okafor, H.E., Mensah, G.A., 2012. Geographic variations in heart failure hospitalizations among medicare beneficiaries in the Tennessee catchment area. *Am. J. Med. Sci.* 343 (1), 71–77.
- Purdy, S., Griffin, T., Salisbury, C., Sharp, D., 2009. Ambulatory care sensitive conditions: terminology and disease coding need to be more specific to aid policy makers and clinicians. *Public Health* 123 (2), 169–173.
- Remes, J., MLEtinen, H., Reunanen, A., Pyörälä, K., 1991. Validity of clinical diagnosis of heart failure in primary health care. *Eur. Heart J.* 12 (3), 315–321.
- Roger, V.L., 2013. Epidemiology of heart failure. *Circulat. Res.* 113 (6), 646–659.
- Saczynski, J.S., Andrade, S.E., Harrold, L.R., Tjia, J., Cutrona, S.L., Dodd, K.S., Gurwitz, J.H., 2012. A systematic review of validated methods for identifying heart failure using administrative data. *Pharmacoepidemiol. Drug Saf.* 21, 129–140.
- Senathirajah, M., Owens, P., Mutter, R., & Nagamine, M. (2011). Special study on the meaning of the first-listed diagnosis on emergency department and ambulatory surgery records. HCUP methods series.
- StataCorp, L.P. (2015). STATA 12 [Computer software]. College Station, TX: StataCorp LP.
- US Office of Management and Budget, 2010. 2010 standards for delineating metropolitan and micropolitan statistical areas; notice. *Federal Register* 75 (123), 37246–37252.
- Vitolins, M.Z., Toozee, J.A., Golden, S.L., Arcury, T.A., Bell, R.A., Davis, C., Quandt, S.A., 2007. Older adults in the rural south are not meeting healthful eating guidelines. *J. Am. Dietetic Assoc.* 107 (2), 265–272 e3.
- Wagnild, G., Rowland, J., Dimmler, L., Peters, D., 2004. Differences between frontier and urban elders with chronic heart failure. *Prog. Cardiovasc. Nurs.* 19 (1), 12–18.
- Yuan, Z., Cooper, G.S., Einstadter, D., Cebul, R.D., Rimm, A.A., 2000. The association between hospital type and mortality and length of stay: a study of 16.9 million hospitalized Medicare beneficiaries. *Med. Care* 38 (2), 231–245.
- Zhang, W., Watanabe-Galloway, S., 2008. Ten-year secular trends for congestive heart failure hospitalizations: an analysis of regional differences in the United States. *Congestive Heart Failure* 14 (5), 266–271.