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Permalink
https://escholarship.org/uc/item/5g61t95c

Journal
Journal of Aging & Social Policy, 34(4)

ISSN
0895-9420

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Publication Date
2022-07-04

DOI
10.1080/08959420.2020.1740639

Peer reviewed

A Multi-Level Analyses of Charges and Cost of Fall-Related Hospitalizations Among Older Adults: Individual, Hospital, and Geospatial Variation

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ABSTRACT

The growing population of older adults has attracted concern from policymakers due in part to the fact that they are at higher risk of costly and potentially injurious falls. Responding to this concern, this study investigated fall-related hospitalizations among those aged 65 and older. Hospitalizations rose from 49,299 to 58,931, with charges and costs (estimated based on charges) increasing from $2.5 billion to $3.6 billion and under $900 million to over$1.1 billion, respectively. The intraclass correlation coefficients from linear mixed-effect models (with charges and costs serving as dependent variables) indicated differences in hospitals accounted for nearly half or more of medical cost variation among older adults suffering a fall-related hospitalization. Nonmetropolitan residence, being aged 65–69 (versus older), and higher risk-of-mortality on admission indicated higher costs. Identifying trends of fall-related hospitalizations over time allows for key stakeholders to not only track the burden of falls among older adults but to also use this information to attract funding for fall prevention strategies from policy makers at various levels (e.g., locally, at the state). Further, identifying characteristics of individuals (e.g., age, race, sex)and places (e.g., rural areas) that carry a higher relative cost can serve to inform the targeted allocation of finite resources including local, state, or federal funding, but also existing evidence-based practices such as community and clinical interventions.

Introduction

The global population aged 65 years or older is expected to triple from 524 million in 2010 to 1.5 billion in 2050 (National Institute on Aging, National Institute of Health & World Health Organization, 2011). In the United States alone, the number of older adults is expected to double from 40.2 to 88.5 million during this time period (Vincent & Velkoff, 2010). Disease and complications associated with aging are more common among those aged 65 years and older, where approximately 75% have two or more chronic diseases (Anderson, 2010). Falls are a serious and costly issue facing the increasing older adult population (Davis et al., 2010). Research shows that having comorbid or multiple chronic conditions (Sibley et al., 2014)(e.g., arthritis (Sturnieks et al., 2004), visual impairment (Reed-Jones et al., 2013; Thurman et al., 2008), or dementia (Thurman et al., 2008) is associated with fall risk and that approximately one-third of American older adults experience a fall every year (Yoshida, 2007). These falls can lead to moderate to severe injuries (Rubenstein & Josephson, 2006) threatening older adults' independence and even causing death (CDC, 2010). They can also have adverse economic consequences.

Studies that seek to estimate the economic burden associated with falls among older adults are necessary (Heinrich et al., 2010); however, estimating the total economic burden of fall-related health expenditures is com-plex given that various economic perspectives may exist when calculating cost (Davis et al., 2010). While not the only aspect of measuring cost, the direct cost of falls among older adults – which may include, but is not limited to the costs of hospitalization, physician costs, and prescription drugs – was estimated to be upwards of 50USD billion in 2015 (Florence et al., 2018). In contrast, the indirect costs of falls, which may include caregiver burden, loss of work, and pain and suffering (Carroll et al., 2008), can be difficult to quantify. Focusing on direct costs can be an effective way to inform policy makers and decision-makers of the economic burden associated with falls.

This study sought to identify individual-level (Perelman & Closon, 2011), hospital-level (Barro, Huckman & Kessler, 2006), and residential-level factors associated with fall-related hospitalizations among older adults. Given that there is scant recent state-wide literature regarding the financial burden of hospital stays after falls, this study examined the cost of fall-related hospitalizations among adults age 65 years and older for 2011, 2012, 2013, and 2014 in Texas, USA. Identifying this information can better inform policy makers about the extent of and trends in fall-related hospitalizations statewide (Haddad et al., 2019), and can also inform clinical settings about the drivers of significant variations in cost. Further, this study can serve as a model to other states to then build upon in larger geographic areas throughout the nation.

Conceptual framework

This study investigated whether the cost of fall-related hospitalizations among those aged 65 and older differed across individual-level characteristics and place-based characteristics (i.e., hospitals, rurality). It was informed by the National Institute on Aging Health Disparities Research Framework (Hill et al., 2015), the World Health Organization's Framework for Action on the Social Determinants of Health (Solar & Irwin, 2010) and other models stressing the role of individual-level and contextual factors, namely ecological models (McLeroy et al., 1988). The theoretical foundation for exploring both individuals- and area-level factors and their potential effect on individual outcomes were taken from the Social Ecological Model (McLeroy et al., 1988) and the World Health Organization's (WHO) Framework for Action on the Social Determinants of Health (Solar & Irwin, 2010). The WHO framework and the Social Ecological Model describe individual-level outcomes (e.g., health-related) as being affected by the interplay between individual-level factors (e.g., age, gender) and environmental factors (e.g., policy, rural/urban differences). Given past evidence highlighted in these theoretical frameworks, it was our expectation that there would be a significant contribution to variation in study outcomes from multiple characteristics at the individual-level, but also at the contextual level (e.g., structural (Solar & Irwin, 2010)). For example, previous research has identified higher rates of falls with increasing age, among females relative to males, and among individuals who were White relative to Hispanic or African American (Towne et al., 2015). This highlights individual-level characteristics that have been shown to play a role in fall-related hospitalizations. Further, past studies identifying the likelihood of being discharged from a fall-related hospitalization to more costly institutionalized settings (versus home) included being White, having a higher risk of mortality, and being female (Towne et al., 2018). Further, research investigating fall mortality using national data identified significant variation in age (older age versus 65–74), sex (being male versus female), and race (being non-White versus White) when predicting a higher likelihood of fall mortality (Moudouni & Phillips, 2013).

Past research, with a geospatial focus, investigated areas with higher rates of fall-related hospitalization, finding that areas with higher rates of Hispanic residents and areas with a higher population density were more likely to be areas designated as "hotspots" or areas with higher rates of fall-related hospitalization (Towne et al., 2019). While this work identified variation by population density, which is related to rurality, other work assessing geospatial factors associated with a different while somewhat related outcome, fall mortality, found no differences by rurality (Moudouni & Phillips, 2013). This research highlights the need to consider area-level factors associated with falls among older adults.

Methods

Data for this study were drawn from all discharges in 2011 (n = 2,937,634), 2012 (n = 2,965,961), 2013 (n = 2,910,853), and 2014 (n = 2,947,191) as recorded in the Texas Hospital Inpatient Discharge Public Use Data Files (PUF) (Texas Hospital Inpatient Discharge Public Use Data File & Health Services). This database included administrative data on hospitalizations including, but not limited to charges for services, diagnostic codes (e.g., ICD-9), and patient demographics (e.g., age group, race, ethnicity, sex) for those discharged from hospitals throughout the state for each year under study. Each hospital discharge has multiple records associated with the hospital stay allowing for detailed analyses of factors associated with a particular hospital stay up to the subsequent discharge from the hospital. Based on our focus of analyzing total hospital costs among older adults, our target population was restricted to any hospital dis-charge among those aged 65 years and older for 2011 (n = 842,658), 2012 (n = 850,118), 2013 (n = 840,874), and 2014 (n = 848,486). From these yearly base populations, we further stratified those discharges with a fall-related hospitalization by year using ICD-9 external-cause-of-injury codes or e-codes that are a supplementary classification of ICD-9 codes (see below). All analyses in the current study thus focus on individuals with e-codes indicating a fall was coded upon admission and who were aged 65 years and older. This study was approved by the Institutional Review Board of the affiliated university of the lead author.

Dependent variable

Total hospital charges at discharge were used to estimate cost (charges multiplied by the cost-to-charge ratio). The total fall-related costs were calculated based on covered and non-covered accommodation and ancillary charges (details are available elsewhere from the Texas Department of State Health Services (TDSHS)). We present both total and average charges and a less crude measure of costs using Medicare cost-to-charge ratios. Previous research used a crude measure of charges to estimate potential costs among a wider age group (Towne et.al., 2014). However, the current study focuses on those that were most likely to qualify for Medicare. Thus, we used the Medicare cost-to-charge ratio to have a more accurate measure of cost. Cost-to-charge ratios (Edelstein & FISPO, 2008) were taken from the Centers for Medicare and Medicaid Services (CMS) (CMS, 2013). We used cost-to-charge ratios based on unique provider numbers for hospitals, where the total costs included charges multiplied by the cost to charge ratio. However, in some cases hospitals had missing information for cost-to-charge ratios, the level of which varied by year. The cost-to-charge ratios were missing for 6.3%, 10.4%, 10.3%, 11.5% of discharges where a fall-related hospitalization was coded for those aged 65 years and older in 2011, 2012, 2013, and 2014, respectively. Therefore, we used the state average cost-to-charge ratio to estimate missing cases. The state averages included 0.366 (2011), 0.355 (2012), 0.331 (2013), and 0.285 (2014).

ICD-9 external-cause-of-injury codes were used to define a fall-related hospitalization. E-codes classifications for falls included 880.0–880.9; 881.0–-881.9; 882.0; 883.0–883.9; 884.0–884.9; 885.0–885.9; 886.0–886.9; 888.0–-888.9, with more detailed information on definitions reported elsewhere (Towne et al., 2014).

Covariates

A unique hospital ID was assigned to each hospital by the Texas Department of State Health Services (DSHS). This variable was used in multi-level analyses to identify differences between hospitals. A geospatial component was added to the analyses to explore differences in the incidence of fall-related hospitalizations and cost by rurality. Rurality of the patients' residential county was measured as metropolitan (metro) areas including large central metro, large fringe metro, medium metro, small metro, and nonmetropolitan areas including micropolitan and noncore using the National Center for Health Statistics 2013 NCHS urban-rural classification scheme for counties (NCHS, (2014).). Sex was treated as male or female. Race and ethnicity were included separately in descriptive analyses. In multivariate analyses, race and ethnicity were combined in one variable defined as non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, non-Hispanic American Indian or Alaska Native, and Hispanic. Age groups included 65–69, 70–74, 75–79, 80–84, 85–89, 90 and older. The risk of mortality was included to adjust for the severity of hospitalization. The variable "risk of mortality" as reported in the PUF (Texas Hospital Inpatient Discharge Public Use Data File & Health Services) was coded as 1) minor, 2) moderate, 3) major, or 4) extreme. Risk of mortality was defined as "Assignment of a risk of mortality score from the All Patient Refined (APR) Diagnosis Related Group (DRG) from the 3M APR-DRG Grouper" (TDSHS).

Statistical analyses

SAS 9.4 (Cary, NC) was used to perform all statistical analyses. We employed chi-square tests to examine if the overall number of falls differed by year. We compared 2 years at a time, (i.e., 2011 to 2012, 2011 to 2013, 2011 to 2014, 2012 to 2013, 2012 to 2014). Linear-mixed models were used to estimate total hospital charges and cost (charges multiplied by the cost-to-charge ratio),while controlling for clustering at the hospital-level. Log transformations were conducted on both charges and cost variables. Fully adjusted models were compared between log-transformed outcomes and non-transformed (i.e., raw) cost and charges. The results were generally consistent between the raw models and log-transformed models. Given the large sample size (Mihaylova et al., 2011) and the consistencies in the conclusions based on raw models and log-transformed models, the non-transformed costs and charges were presented here for easier interpretation purposes. The linear mixed-effect models were fit using data from each year separately first. Then, in order to compare mean charges and cost over time, we ran two pooled models (i.e., merging data from 4 years together) including a year as a covariate, one with non-log transformed charges and one with non-transformed costs as the outcome variable. Only fully adjusted analyses from our outcomes by year separately are presented in tables given this is the major focus.

Clustering was measured at the hospital-level using the unique hospital ID assigned by the Department of Health and Human Services (TDSHS, 2018). Intraclass correlation coefficients (ICCs) were calculated using the empty model without predictors (Bell et al., 2013). The fully adjusted model included sex, age, race/ethnicity, risk of mortality, and rurality, and the interaction between sex and risk of mortality and the interaction between rurality and risk of mortality while incorporating a random intercept at the hospital-level. The overall distribution of fall-related hospitalizations among older adults is presented, followed by detailed information on the cost of fall-related hospitalizations for each year. Finally, we provide estimates based on adjusted analyses accounting for individual-level factors, hospital clustering, and geospatial location.

Results

Table 1 presents the distribution of fall-related hospitalizations among adults aged 65 years and older. Over 200,000 fall-related hospitalizations occurred among those aged 65 years and older in 2011, 2012, 2013, and 2014 combined. The number of falls grew each year with 49,299 in 2011 reaching 58,931 in 2014. Females accounted for nearly 70% of fall-related hospitalizations across the study years. In addition, non-Hispanic White individuals accounted for close to 75% of fall-related hospitalizations for each year under study. Individuals of Hispanic origin accounted for approximately 17–19% of all fall-related hospitalizations for each study year. Residents of more metropolitan areas accounted for the vast majority of fall-related hospitalizations among older adults across the study years with the most rural areas accounting for less than 10% of fall-related hospitalizations.

The overall number of fall-related hospitalizations among those aged 65 years and older was significantly higher over time including comparisons from 2011 to 2012, 2011 to 2013, 2011 to 2014, 2012 to 2013, 2012 to 2014, and 2013 to 2014 ($p < .0001$ for all comparisons, data not shown).

Tables 2a and 2b provide a snapshot of the total cost of fall-related hospitalization by selected characteristics among those aged 65 years and older. Females accounted for the majority of costs in all years under study. In addition, individuals who were categorized as non-Hispanic White accounted for higher costs than any other racial or ethnic group. Individuals aged 80–84 years accounted for the highest charges and costs among all age groups, followed by those 85–89 years. The majority of total fall-related hospitalization charges were among those residing in more metropolitan areas.

The unadjusted mean charges of fall-related hospitalizations per patient discharge was calculated for overall comparisons across each time point among those aged 65 years and older. The overall mean charges were 50,280USD in 2011, 54,372USD in 2012, 59,010USD in 2013 and 61,866USD in 2014. This represents an overall increase of more than 11,000USD from 2011 to 2014, increasing each year. The average cost of fall-related hospitalization were calculated as well. The overall adjusted mean cost was 17,784USD in 2011, 18,599USD in 2012, 17,946USD in 2013, and 18,815USD in 2014. This represents an overall increase of more than 1,000USD from 2011 to 2014, with the highest cost across all years in 2014. Generally, the average charges and cost were higher for males, those aged 65–69, and those with the highest risk of mortality on admission.

Table 1. Distribution of fall-related hospitalizations in the target population aged 65 years and older by selected characteristics.

		2011		2012		2013		2014	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Total	Age 65 and older	49,299	100	51,901	100	54,640	100	58,931	100
Rurality	Large central metro	20,025	41.84	21,194	42.16	22,177	41.99	24,496	43.05
	Large fringe metro	8,394	17.54	9,176	18.25	9,758	18.47	10,605	18.64
	Medium metro	8,019	16.75	8,789	17.48	9,134	17.29	9,569	16.82
	Small metro	4,048	8.46	3,758	7.48	4,010	7.59	4,142	7.28
	Micropolitan	3,787	7.91	3,809	7.58	4,039	7.65	4,108	7.22
	Noncore	3,591	7.50	3,548	7.06	3,703	7.01	3,979	6.99
Sex	Female	33,805	68.57	35,350	68.11	36,752	67.26	39,344	66.76
	Male	15,493	31.43	16,550	31.89	17,887	32.74	19,586	33.24
Race	American Indian/Alaska Native	437	0.93	354	0.75	112	0.22	24	0.04
	Asian or Pacific Islander	488	1.03	479	1.02	833	1.61	922	1.64
	Black	2278	4.83	2275	4.85	2577	4.99	2870	5.12
	White	35,922	76.11	35,135	74.84	38,804	75.21	42,151	75.16
	Hispanic	8072	17.10	8704	18.54	9269	17.96	10,112	18.03
Age	65–69 years	5,374	10.90	5,878	11.33	6,572	12.03	7187	12.20
	70–74	6,529	13.24	7,048	13.58	7,564	13.84	8441	14.32
	75–79	8,447	17.13	8,885	17.12	9,388	17.18	10,110	17.16
	80–84	10,875	22.06	11,197	21.57	11,663	21.35	12,206	20.71
	85–89	10,734	21.77	10,947	21.09	10,851	19.86	11,704	19.86
	90+	7,340	14.89	7,946	15.31	8,602	15.74	9283	15.75

Table 2a. Charges and cost of fall-related hospitalization by year among those aged 65 years and older.

		2011		2012		2013		2014	
		2,685,276		2,817,979		2,954,614		3,082,092	
Texas Population ≥65 (n)		Charges	Cost	Charges	Cost	Charges	Cost	Charges	Cost
Total cost among those ≥65		$2478.77 M	$876.73 M	$2821.94 M	$965.29 M	$3224.30 M	$980.59 M	$3645.84 M	$1108.77 M
Rurality	Large central metro	$1028.14 M	$377.72 M	$1150.07 M	$407.81 M	$1306.83 M	$385.46 M	$1498.01 M	$441.73 M
	Large fringe metro	$426.44 M	$166.50 M	$505.47 M	$161.89 M	$573.93 M	$162.47 M	$657.72 M	$186.13 M
	Medium metro	$439.42 M	$141.01 M	$520.37 M	$180.00 M	$599.70 M	$197.96 M	$677.70 M	$225.09 M
	Small metro	$176.46 M	$57.43 M	$184.23 M	$62.28 M	$212.62 M	$71.28 M	$221.51 M	$74.27 M
	Micropolitan	$169.84 M	$55.90 M	$187.29 M	$62.66 M	$219.98 M	$67.44 M	$236.33 M	$72.38 M
	Noncore	$159.90 M	$50.30 M	$175.41 M	$58.36 M	$195.24 M	$59.55 M	$217.13 M	$65.74 M
Sex	Female	$1635.71 M	$577.24 M	$1833.15 M	$627.70 M	$2076.28 M	$634.44 M	$2345.97 M	$714.10 M
	Male	$843.03 M	$299.47 M	$988.77 M	$337.58 M	$1148.02 M	$346.15 M	$1299.86 M	$394.67 M
Race and Ethnicity	American Indian/Alaska Native	$24.47 M	$9.10 M	$17.87 M	$7.40 M	$6.70 M	$2.33 M	$1.20 M	$0.35 M
	Asian or Pacific Islander	$27.85 M	$10.12 M	$28.46 M	$9.05 M	$50.40 M	$19.17 M	$52.18 M	$20.15 M
	Black	$116.19 M	$41.08 M	$129.28 M	$45.25 M	$152.96 M	$44.39 M	$174.36 M	$49.59 M
	White	$1755.03 M	$636.02 M	$1886.03 M	$634.12 M	$2225.91 M	$657.06 M	$2505.43 M	$741.54 M
	Hispanic	$451.00 M	$145.06 M	$533.14 M	$194.00 M	$617.01 M	$202.42 M	$731.93 M	$241.1 M
Age	65–69 years	$292.79 M	$104.47 M	$359.03 M	$122.48 M	$440.70 M	$132.00 M	$492.42 M	$148.01 M
	70–74	$355.55 M	$127.75 M	$413.12 M	$141.53 M	$470.81 M	$141.27 M	$551.37 M	$166.98 M
	75–79	$431.28 M	$154.03 M	$496.03 M	$168.77 M	$569.74 M	$173.57 M	$660.92 M	$202.77 M
	80–84	$546.96 M	$192.98 M	$610.60 M	$208.85 M	$694.47 M	$212.68 M	$745.69 M	$226.80 M
	85–89	$522.85 M	$183.63 M	$571.00 M	$196.70 M	$607.95 M	$187.04 M	$695.12 M	$211.70 M
	90+	$329.34 M	$113.85 M	$372.17 M	$126.97 M	$440.62 M	$134.02 M	$500.32 M	$152.50 M
Risk of Mortality	Minor	$404.02 M	$141.33 M	$421.47 M	$142.99 M	$534.74 M	$166.09 M	$602.04 M	$185.00 M
	Moderate	$960.04 M	$336.61 M	$1042.01 M	$356.28 M	$1172.85 M	$359.27 M	$1323.57 M	$407.35 M
	Major	$645.35 M	$231.30 M	$771.20 M	$263.04 M	$992.46 M	$296.99 M	$1118.95 M	$335.91 M
	Extreme	$469.35 M	$167.49 M	$587.26 M	$202.97 M	$524.13 M	$158.20 M	$601.28 M	$180.50 M

Currency reported in million e.g., $2478.77 M is equivalent to $2,478,771,197 and $9.10 M is equivalent to $9,101,819

Table 2b. Average charges and cost of fall-related hospitalization by year among those aged 65 years and older.

		2011		2012		2013		2014	
		Mean Charges	Mean Cost	Mean Charges	Mean Cost	Mean Charges	Mean Cost	Mean Charges	Mean Cost
Mean cost among those ≥65		$50,280	$17,784	$54,372	$18,599	$59,010	$17,946	$61,866	$18,815
Rurality	Large central metro	$51,343	$18,863	$54,264	$19,242	$58,927	$17,381	$61,153	$18,033
	Large fringe metro	$50,803	$19,836	$55,086	$17,642	$58,816	$16,649	$62,020	$17,551
	Medium metro	$54,797	$17,584	$59,207	$20,480	$65,656	$21,673	$70,822	$23,523
	Small metro	$43,592	$14,187	$49,023	$16,573	$53,022	$17,775	$53,479	$17,930
	Micropolitan	$44,848	$14,760	$49,170	$16,450	$54,463	$16,697	$57,529	$17,619
	Noncore	$44,527	$14,008	$49,438	$16,450	$52,725	$16,082	$54,570	$16,523
Sex	Female	$48,387	$17,076	$51,857	$17,757	$56,494	$17,263	$59,627	$18,150
	Male	$54,413	$19,330	$59,744	$20,398	$64,182	$19,352	$66,367	$20,150
Race and Ethnicity	American Indian/Alaska Native	$55,994	$20,828	$50,476	$20,910	$59,807	$20,792	$49,994	$14,542
	Asian or Pacific Islander	$57,071	$20,734	$59,422	$18,902	$60,510	$23,016	$56,594	$21,856
	Black	$51,006	$18,033	$56,828	$19,891	$59,356	$17,225	$60,753	$17,279
	White	$48,857	$17,706	$53,680	$18,048	$57,363	$16,933	$59,439	$17,593
	Hispanic	$55,872	$17,970	$61,252	$22,288	$66,567	$21,838	$72,383	$23,843
Age	65–69 years	$54,483	$19,441	$61,080	$20,837	$67,058	$20,086	$68,515	$20,595
	70–74	$54,457	$19,567	$58,615	$20,080	$62,244	$18,677	$65,320	$19,782
	75–79	$51,057	$18,235	$55,828	$18,995	$60,688	$18,489	$65,373	$20,056
	80-84	$50,295	$17,746	$54,533	$18,652	$59,545	$18,235	$61,092	$18,581
	85–89	$48,709	$17,108	$52,160	$17,968	$56,027	$17,237	$59,392	$18,088
	90+	$44,869	$15,511	$46,837	$15,978	$51,223	$15,580	$53,897	$16,428
Risk of Mortality	Minor	$37,724	$13,196	$40,132	$13,616	$44,521	$13,829	$47,937	$14,731
	Moderate	$42,631	$14,947	$45,213	$15,459	$49,188	$15,067	$51,811	$15,946
	Major	$57,000	$20,429	$60,316	$20,572	$67,036	$20,060	$68,820	$20,660
	Extreme	$98,874	$35,284	$105,528	$36,473	$131,891	$39,808	$131,658	$39,523

Changes over time

The average charges of fall-related hospitalization increased from 2011 to 2012, 2013, and 2014 and from 2012 to 2013, and 2014 and from 2013 to 2014 in analyses using pooled data for all years ($p < .0001$ for all comparisons, data not shown).

The average costs of fall-related hospitalizations increased from 2011 to 2012 and 2014 and from 2012 to 2013 and from 2013 to 2014 in analyses using pooled data for all years ($p < .0001$ for all comparisons, data not shown).

Adjusted analyses

Table 3 presents results from fully adjusted analyses based on data by year separately. The estimated intraclass correlation coefficients (ICCs) for the charges in year 2011–2014 ranged from 0.42 to 0.67, which means approximately 42–67%(depending on the year) of the variation in charges was accounted for by differences between hospitals. Individuals aged 65–69 years had higher average charges than those in older age groups after controlling for all other terms in the model.

When considering the interaction of risk of mortality and sex, we find the adjusted charges were generally higher with increasing risk of mortality for both males and females, with the highest adjusted charges seen for males in extreme risk of mortality within each year.

When considering the interaction of risk of mortality and rurality, we found the average charge of fall-related hospitalization among those aged 65 years and older was generally lowest among individuals in the most urban areas among those with minor risk of mortality. Among those with minor risk of mortality, those in the most rural areas had significantly higher adjusted charges than those in the most urban areas in each year. Among those in higher levels of mortality, we generally found that within each level of mortality (excluding minor) those in the second most urban areas (large fringe metro areas) and in the most rural areas (noncore) had higher relative charges than those in the most urban areas, after adjusting for all other terms in the model.

Table 4 presents results from fully adjusted analyses based on data by year separately. Approximately 46–70% (depending on the year) of the variation in costs was accounted for by differences between hospitals. Individuals aged 65–69 years had higher average costs than those in older age groups after controlling for all other terms in the model.

When considering the interaction of risk of mortality and sex, we find the adjusted costs were generally higher with increasing risk of mortality for both males and females, with the highest adjusted costs seen for males in extreme risk of mortality within each year.

Table 3. Adjusted analyses of average charges of fall-related hospitalization for those aged 65 years and older.

		2011		2012		2013		2014	
		Mean	p-value	Mean	p-value	Mean	p-value	Mean	p-value
Rurality	Large central metro (ref.)	61747	0.0215	65948	<.0001	76009	0.0307	72386	0.0003
	Large fringe metro	63804**		69704**		75817		73669	
	Medium metro	62406		64564		81720**		78267**	
	Small metro	61058		69074		78854		75820	
	Micropolitan	62790		67183		77874		79315**	
	Noncore	64070*		68955*		79908*		77489**	
Sex	Female (ref.)	61363	<.0001	65951	<.0001	76962	<.0001	75208	0.0009
	Male	63929**		69191**		79765**		77108**	
Race	American Indian/Alaska Native	65208	0.0218	66506	0.0656	86756	0.2600	65639	0.0748
	Asian or Pacific Islander	65518*		72134*		75662		75651*	
	Black	59481*		65121		75316		78845	
	White (ref.)	61481		67031		76986		80176	
	Hispanic	61540		67063		77097		80477	
Age	65-69 years (ref.)	68692	<.0001	74649	<.0001	86944	<.0001	84223	<.0001
	70-74	65382**		70519**		81408**		78974**	
	75-79	62900**		68525**		79401**		78669**	
	80-84	62167**		67089**		77836**		74554**	
	85-89	60213**		64737**		75065**		72732**	
	90+	56520**		59909**		69527**		67793**	
Risk of Mortality (Risk)	Minor (ref)	41899	<.0001	45754	<.0001	51348	<.0001	49942	<.0001
	Moderate	48076**		52488**		57888**		56620**	
	Major	61764**		65589**		74456**		71671**	
	Extreme	98844**		106454**		129762**		126398**	
Sex* Risk of Mortality	Female | Risk at Minor (ref.)	42466	<.0001	45758	<.0001	52121	<.0001	51587	<.0001
	Female | Risk at Moderate	48644**		52967**		58306**		57363**	
	Female | Risk at Major	61345**		65371**		73197**		71616**	
	Female | Risk at Extreme	92996**		99709**		124222**		120264**	
	Male | Risk at Minor	41332		45749		50575		48296**	
	Male | Risk at Moderate	47508**		52009**		57470**		55877**	
	Male | Risk at Major	62183**		65806**		75715**		71727**	
	Male | Risk at Extreme	104693**		113199**		135302**		132531**	

(*Continued*)

Table 3. (Continued).

		2011		2012		2013		2014	
		Mean	p-value	Mean	p-value	Mean	p-value	Mean	p-value
Rurality* Risk of Mortality	Large central metro | Risk at Minor (ref.)	39296	<.0001	42722	<.0001	46531	<.0001	44469	<.0001
	Large fringe metro | Risk at Minor	46201		49525*		52553		50360	
	Medium metro | Risk at Minor	59373		62742		69637		66387	
	Small metro | Risk at Minor	102116		108801*		135313**		128327**	
	Micropolitan | Risk at Minor	41135**		46441		48207**		46959**	
	Noncore | Risk at Minor	47323**		51527**		54205**		52164**	
	Large central metro | Risk at Moderate(ref.)	60774**		67182**		73860**		70386**	
	Large fringe metro | Risk at Moderate	105982**		113665**		126996**		125166**	
	Medium metro | Risk at Moderate	38681**		40455**		49076**		44838**	
	Small metro | Risk at Moderate	46465**		49043**		57916**		54935**	
	Micropolitan | Risk at Moderate	61221**		63602**		76969**		73396**	
	Noncore | Risk at Moderate	103257**		105154**		142918**		139897**	
	Large central metro | Risk at Major (ref.)	42953**		48949**		54026**		55041**	
	Large fringe metro | Risk at Major	48216**		54263**		60915**		61199**	
	Medium metro | Risk at Major	59853**		65812**		74985**		71498**	
	Small metro | Risk at Major	93208**		107272**		125490**		115542**	
	Micropolitan | Risk at Major	45237**		46614**		54264**		54958**	
	Noncore | Risk at Major	50309**		54228**		60388**		59634**	
	Large central metro | Risk at Extreme (ref.)	64096**		67239**		75749**		72739**	
	Large fringe metro | Risk at Extreme	91520**		100652**		121094**		129930**	
	Medium metro | Risk at Extreme	44090**		49342**		55985**		53385**	
	Small metro | Risk at Extreme	49943**		56342**		61351**		61427**	
	Micropolitan | Risk at Extreme	65265**		66955**		75537**		75622**	
	Noncore | Risk at Extreme	96982**		103181**		126760**		119524**	

* $p < .05$

** $p < .01$

Intra-class correlation coefficients (ICCs) for cost were 0.46 for 2011, 0.50 for 2012, 0.57 for 2013, and 0.70 for 2014.

Analyses is adjusted for rurality, sex, race, ethnicity, age group, risk of mortality, the interaction between the risk of mortality and sex, and the interaction between the risk of mortality and rurality, while also accounting for the nested nature of the data using linear-mixed models.

Table 4. Adjusted analyses of average costs of fall-related hospitalization for those aged 65 years and older.

		2011		2012		2013		2014	
		Mean	p-value	Mean	p-value	Mean	p-value	Mean	p-value
Rurality	Large central metro (ref.)	22359	0.0003	22584	0.0002	23878	<.0001	22915	<.0001
	Large fringe metro	23587**		23954**		23357		23245	
	Medium metro	22203		22127		26195**		25243**	
	Small metro	21582		23432		25237*		23860	
	Micropolitan	22425		23237		24690		24993**	
	Noncore	22642		23588		25516**		24627**	
Sex	Female (ref.)	21994	<.0001	22652	<.0001	24468	0.0006	23878	0.0035
	Male	22939**		23655**		25157**		24417**	
Race	American Indian/Alaska Native	23603	0.0058	22265	0.1422	27072	0.2178	20186	0.1744
	Asian or Pacific Islander	23782*		24793*		23682		24434	
	Black	21082*		22492		24149		25079	
	White (ref.)	21961		23087		24659		25505	
	Hispanic	21906		23131		24499		25533	
Age	65-69 years (ref.)	24617	<.0001	25549	<.0001	27205	<.0001	26603	<.0001
	70-74	23435**		24252**		25653**		24939**	
	75-79	22476**		23387**		25188**		24977**	
	80-84	22343**		23019**		24714**		23654**	
	85-89	21608**		22100**		23882**		23114**	
	90+	20320**		20614**		22231**		21596**	
Risk of Mortality (Risk)	Minor (ref)	15285	<.0001	15754	<.0001	16593	<.0001	16223	<.0001
	Moderate	17334**		18014**		18641**		18332**	
	Major	22318**		22361**		23574**		22924**	
	Extreme	34930**		36486**		40442**		39110**	
Sex* Risk or Mortality	Female | Risk at Minor (ref.)	15441	<.0001	15766	<.0001	16816	<.0001	16786	<.0001
	Female | Risk at Moderate	17595**		18167**		18778**		18555**	
	Female | Risk at Major	21997**		22270**		23282**		22867**	
	Female | Risk at Extreme	32944**		34406**		38996**		37304**	
	Male | Risk at Minor	15128		15741		16370		15660**	
	Male | Risk at Moderate	17073**		17860**		18503**		18110**	
	Male | Risk at Major	22639**		22453**		23866**		22980**	
	Male | Risk at Extreme	36915**		38565**		41888**		40916**	

(Continued)

Table 4. (Continued).

		2011		2012		2013		2014	
		Mean	p-value	Mean	p-value	Mean	p-value	Mean	p-value
Rurality* Risk or Mortality	Large central metro (ref.) | Risk at Minor (ref.)	14138	<.0001	14239	<.0001	15333	<.0001	14667	<.0001
	Large fringe metro | Risk at Minor	16559		16746**		17004		16488*	
	Medium metro | Risk at Minor	21692		21313		21964		21180	
	Small metro | Risk at Minor	37048*		38038**		41212		39323**	
	Micropolitan | Risk at Minor	14681**		16445*		16069**		15852**	
	Noncore | Risk at Minor	16870**		18010**		17713**		17227**	
	Large central metro (ref.) | Risk at Moderate	22390**		22895**		22820**		22165**	
	Large fringe metro | Risk at Moderate	40405**		38466**		36825**		37736**	
	Medium metro | Risk at Moderate	14393**		13749**		15562**		14534**	
	Small metro | Risk at Moderate	16724**		16678**		18437**		17901**	
	Micropolitan | Risk at Moderate	21848**		21690**		24739**		23974**	
	Noncore | Risk at Moderate	35849**		36390**		46044**		44565**	
	Large central metro (ref.) | Risk at Major	15664**		16832**		16820**		17622**	
	Large fringe metro | Risk at Major	17534**		18654**		19357**		19289**	
	Medium metro | Risk at Major	21556**		22553**		23662**		22626**	
	Small metro | Risk at Major	31575**		35687**		41109**		35902**	
	Micropolitan | Risk at Major	16658**		16177**		17557**		17686**	
	Noncore | Risk at Major	18178**		18793**		19632**		19291**	
	Large central metro (ref.) | Risk at Extreme	23247**		23130**		24245**		23508**	
	Large fringe metro | Risk at Extreme	31619**		34850**		37326**		39488**	
	Medium metro | Risk at Extreme	16175**		17080**		18216**		16980**	
	Small metro | Risk at Extreme	18140**		19201**		19702**		19796**	
	Micropolitan | Risk at Extreme	23174**		22588**		24012**		24089**	
	Noncore | Risk at Extreme	33080**		35484**		40133**		37644**	

* $p < .05$

** $p < .01$

Intra-class correlation coefficients (ICCs) for charges were 0.43 for 2011, 0.49 for 2012, 0.50 for 2013, and 0.67 for 2014.

Analyses is adjusted for rurality, sex, race, ethnicity, age group, risk of mortality, the interaction between the risk of mortality and sex, and the interaction between the risk of mortality and rurality, while also accounting for the nested nature of the data using linear-mixed models.

When considering the interaction of risk of mortality and rurality, we found the average cost of fall-related hospitalization among those aged 65 years and older was generally lowest among individuals in the most urban areas among those with minor risk of mortality. Among those with minor risk of mortality, those in the most rural areas had significantly higher adjusted costs than those in the most urban areas in each year. Among those in higher levels of mortality, we found that within each level of mortality (excluding minor) those in the second most urban areas (large fringe metro areas) and in the most rural areas (noncore) had higher relative costs than those in the most urban areas, after adjusting for all other terms in the model.

Discussion

Consistent with national projections in the growth of the older adult population, the number of fall-related hospitalizations increased across all years of study among those aged 65 years and older. The total charges of fall-related hospitalizations among those aged 65 years and older were more than 3.6USD billion in 2014, up from less than 2.5USD billion in 2011. In terms of percent increase, the growth in cost outpaced the growth in the population of adults aged 65 years and older in Texas at the same time. The same was true for estimated costs. More specifically, the total charges of fall-related hospitalizations among those aged 65 years and older increased from nearly 2.5USD billion in 2011 to 2.8USD billion in 2012, 3.2USD billion in 2013 and over 3.6USD billion in 2014. This represents a percent change (growth) of nearly 47% across the entire study period. The total costs (charges multiplied by the cost to charge ratio) also increased over time from less than 900USD million in 2011 to over 1.1USD billion in 2014. This represents a percent change (growth) of nearly 27%. This percentage well exceeds growth in the population aged 65 year and older, which increased from approximately 2.6 million in 2011 to over 3 million in 2014, a percent change (growth) of nearly 15%.

The variation in charges and cost attributable to clustering at the hospital level (i.e., variation attributable to being treated in one hospital versus another) was high. This variation in charges and cost may be due to a variety of factors; however, it remains an important component in under-standing the factors associated with medical costs attributed to fall-related hospitalizations. For example, some have suggested increases in medical charges by hospitals may be related to outlier payment mechanisms from CMS, given certain incentives to increase prices to qualify for outlier payments (Levinson, 2013). More research into why this variation exists is needed to identify targets for improving costs.

The growth in older adults is expected to increase dramatically in developed nations and even more so in developing nations (World Health Organization, 2011). Falls and fall-related injuries are expected to increase due to the growing older population globally (World Health Organization, 2007). Thus, access to and utilization of fall prevention strategies for older community-dwelling individuals are critical. Further, policy makers and other key stakeholders have increasingly recognized the role of not only individual-level characteristics and their relationship in identifying differential health and related outcomes, but also the major contribution that context and/or structural determinants of health play. For example, the World Health Organization (Solar & Irwin, 2010) and the US NIH (Hill et al., 2015) highlight the critical role of context (e.g., place-based or policy-level characteristics). This was reinforced in the current state-level study. State-wide surveillance efforts can use this study to identify relevant factors to consider when assessing the burden of falls among older adults, which can inform stakeholders with critical and actionable data in efforts to conduct interventions in community and clinical settings. Thus, this work serves as a state-wide model to provide relevant and timely information to inform public policy.

Limitations

The PUF was at the discharge-level and not necessarily at the patient-level. Individuals may have been included multiple times given one may be admitted and discharged multiple times throughout the year. Even so, the ability to assess the total costs of nearly every discharge for 4 years was a major strength. Further, we applied the state average cost-to-charge ratio to estimate missing cases in which the cost-to-charge ratio was missing. While the level of missing data was low, missing data was not negligible and as such we did not conduct complete case analyses (Jakobsen et al., 2017). Using simple mean imputation is not without limitations, though the relatively small percent of hospitals with missing data (i.e., 6.3%-11.5%) may limit some potential bias (Dziura et al., 2013; Schulz & Grimes, 2002) making this approach a feasible alternative. Furthermore, the cost-to-charge ratios are applied at the hospital thereby applying the same ratio to all patients in a given hospital. Characteristics of hospitals included in the data were extremely limited making more detailed imputations (e.g., multiple imputations) informed by all relevant information impossible. Therefore, we chose a simple mean imputation. The methods for addressing missing data can be complex and agreement on a given approach may vary. For example, approaches to address missing data may include using single or multiple imputations (Gómez-Carracedo et al., 2014; Jakobsen et al., 2017), however, deciding on a particular approach should be informed by considering multiple issues. While a full discussion of these approaches is beyond the scope of this study, we recommend future studies explore the potential implications of using multiple methods (Nasir et al., 2016) with similar data. While we were able to account for major predictors of fall-related hospitalization (e.g., age, risk of mortality), we did not have detailed information on the full scope of factors that may influence fall-related hospitalizations (e.g., detailed injury types and related causes). Further research that explores other more direct factors associated with fall-related hospitalization is recommended. While the hospital's teaching status is not included in the fully adjusted analyses, it was included in exploratory analyses and indicated no significant association ($p < .05$, data not shown) with variation in cost. The PUF was limited in terms of not having all characteristics of hospitals that may affect cost. For example, theoretical frameworks informing our study highlight multiple structural or contextual factors, yet our analyses were limited to using rurality and hospital as the major contextual characteristic in analyses. Examination of hospital characteristics influencing cost is highly recommended for future research, as this will narrow the knowledge gap into understanding both major drivers in higher cost and factors associated with potential cost savings. However, we were able to include both individual and geospatial characteristics of individuals and their residence in addition to accounting for the nested structure of the data.

The PUF used in this study did not include records for counties with fewer than five discharges per quarter. In addition, the age grouping used for patients with HIV/AIDS was not consistent with that of all other observations (i.e., larger age ranges) and as such was excluded from the current analyses. Finally, for multi-level models, we were restricted to hospitals with a unique hospital ID. Hospitals with fewer than 50 discharges in a single quarter were assigned a single ID that prevented distinguishing them for analyses in the PUF. Furthermore, it was not possible to determine whether individuals traveled to the nearest hospital for treatment, as the patient address was absent from the PUF. Finally, cost and charges are not normally distributed in many cases. Thus, potential bias may be introduced when using models that assume normality in our outcomes (i.e., a normal distribution). While we did compare both log-transformed models and raw charges and cost, we found the results were generally consistent between the raw models and log-transformed models. The decision to present raw charges and costs was also informed by the relatively large sample size in the current analyses (Mihaylova et al., 2011). Even so, it is possible some degree of bias may have been introduced in our analyses. Findings should be interpreted in light of these limitations.

Conclusions

This study reinforces the importance of identifying variation in charges and cost across hospitals throughout states. Policy makers, who are increasingly interested in bringing down the high costs of medical care, can use this information to inform resource allocation, such as grant funding to evidence-based practices (e.g., fall prevention programs delivered in the community and clinical settings). Those in clinical settings, such as administrators who are involved in increasing quality of care, can use this study as a means of informing continued analyses (e.g., continuous quality improvement) of potential mechanisms associated with higher costs and determine if quality and costs follow similar patterns. Further, patients, who are increasingly concerned about the cost of medical care, may benefit from ongoing investigations into lowering cost, while also improving the quality of care received. State-wide analyses are valuable to both local and state-wide stakeholders. Identifying, trends, namely increases in the incidence and the cost of fall-related hospitalizations and factors related to cost (e.g., risk of mortality, rurality) can help inform stakeholders (e.g., practitioners, researchers, policy-makers) about the magnitude of falls in their respective states, thus informing policy makers about the growing and somewhat ameliorable cost of falls across the US. Findings suggest that an older adult’s residence setting (i.e., living in rural areas) impacts fall-related hospitalization costs and that large variations in cost are attributable to hospitals. US per capita medical cost of falls among older adults were higher than Australia and the UK (Heinrich et al., 2010); as such, national analyses may then allow for global comparisons of national fall-related costs among older adults, further increasing understanding of macro-level factors influencing individual outcomes.

Ethical approval
This study was considered exempt and approved by the Institutional Review Board (IRB # IRB2013–0774M) of the affiliated university of the lead author (Texas A&M University).

Disclosure statement
No potential conflict of interest was reported by the authors.

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