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Trends in Mortality and Medical Spending in Patients Hospitalized for Community-Acquired Pneumonia: 1993 – 2005

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Background: Community-acquired pneumonia (CAP) is the most common infectious cause of death in the United States. To understand the impact of efforts to improve quality and efficiency of care in CAP, we examined trends in mortality and costs among hospitalized CAP patients.

Methods: Using the National Inpatient Sample from 1993–2005, we studied 569,524 CAP admissions. The primary outcome was mortality at discharge. We used logistic regression to evaluate the mortality trend, adjusting for age, gender, and comorbidities. To account for the impact of early discharge practices, we also compared daily mortality rates and performed a Cox proportional-hazards model. We used a generalized linear model to analyze trends in hospitalization costs, which were derived using cost-to-charge ratios.

Results: Over time, length of stay (LOS) declined, while more patients were discharged to other facilities. The frequency of many comorbidities increased. Age/gender-adjusted mortality decreased from 8.9% to 4.1% ($P < 0.001$). In multivariable analysis, the mortality risk declined through 2005 (odds ratio, 0.50; 95% confidence interval [CI], 0.48–0.53), compared to reference year 1993. The daily mortality rates demonstrated that most of the mortality reduction occurred early during hospitalization. After adjusting for early discharge practices, the risk of mortality still declined through 2005 (hazard ratio, 0.74, 95% CI 0.70–0.78). Median hospitalization costs exhibited a modest reduction over time, mostly due to reduced LOS.

Conclusions: Mortality among patients hospitalized for CAP has declined. Lower **in-hospital** mortality at a reduced cost **suggests that** pneumonia **is** a case of improved productivity in health care.

INTRODUCTION

Community-acquired pneumonia (CAP) is the most common infectious cause of death in the United States. Hospitalization rates for CAP have increased, as have comorbidities among these patients.[1] The substantial treatment costs of CAP were estimated at $12.2 billion during the late 1990s,[2] with additional costs in lost productivity.[3]

There has been a great deal of research on measures to improve the quality and efficiency of care for CAP patients.[4, 5] Pneumococcal vaccination (PV), influenza vaccination (IV), combination antibiotic therapy, early antibiotics, and obtaining blood cultures are associated with reduced mortality.[6-9] These process measures are being used as quality indicators by the Centers for Medicare and Medicaid Services' Hospital Compare quality initiative, and will likely be increasingly linked to payments.[10]

Despite these efforts, the impact of more widespread use of these interventions on mortality has not been measured. Especially with increasing hospitalization rates, it is important to understand trends in mortality, length of stay (LOS), and costs of care for community populations. We therefore examined these trends in hospitalized CAP patients.

METHODS

Data Source, Study Population, and Data Elements

Our analysis used hospitalizations from a 10% subsample of the Healthcare Cost and Utilization Project's National Inpatient Sample (NIS) from 1993–2004, as well as the full sample from 2005, for which no subsample is provided. This nationally representative, all-payer

database has been described elsewhere.[11] Hospitalizations for CAP in patients aged ≥ 18 years were identified using *International Classification of Diseases, Ninth Revision, Clinical Modification* codes recorded at discharge. A hospitalization met the diagnostic criteria by either a principal diagnosis of pneumonia (codes 481–486) or a principal diagnosis of respiratory distress (code 786) or respiratory failure (code 518) with a secondary pneumonia diagnosis. This code combination has an 84% sensitivity and 86% specificity, compared to clinical chart review.[12]

Patient age, sex, admission source, discharge diagnoses, LOS, total charge, and discharge disposition were obtained from the record of each applicable hospitalization. Using the Elixhauser AHRQ Comorbidity Software, 29 binary comorbidity indicator variables (CIVs) were defined based on the discharge diagnoses.[13]

We performed additional analyses to account for the potential impact of changing admission, discharge, and coding practices. There has been increased on-site treatment of long-term care (LTC) facility residents who develop pneumonia.[14] Since this subgroup has a very high mortality rate, a trend toward on-site treatment might artifactually decrease mortality among hospitalized patients. The NIS does not capture patients treated at LTC facilities without transfer to an acute-care hospital. Therefore, to assess for the sensitivity of our results to more frequent on-site treatment, we performed an analysis eliminating all patients admitted from a LTC facility. There has also been a trend toward earlier hospital discharge and transfer to skilled nursing facilities (SNFs) and intermediate care facilities (ICFs), as well as discharge with home health care (HHC).[15] Finally, the number of fields available for coding diagnoses has increased, resulting in

more frequent coding of comorbidities. We describe below analyses to assess the sensitivity of our results to these factors.

Costs were calculated from hospital charges, using cost-to-charge ratios (CCRs) provided by AHRQ.[16, 17] CCRs were not available for all hospitals in all years. We therefore used a prioritization scheme (details in the appendix) to estimate each hospital's CCR. If a hospital-specific CCR was unavailable for a particular year, the hospital-specific CCR from a proximate year was used. In such cases, per AHRQ recommendations, a 3% increase or decrease in the CCR was applied when going backward or forward in time, respectively.[16] If a hospital-specific CCR was unavailable, we used the hospital group average CCR, which is a weighted average for hospitals in the group, defined based on state, urban/rural location, investor-owned/other, and number of beds. If this group average was also unavailable, we used the average CCR in the hospital's NIS stratum, which is assigned based on region, ownership type, urban/rural location, teaching/nonteaching status, and number of beds. CCRs were not available for 1993–1996, and 1998, so these were imputed based on 1997 and 1999 CCRs with the aforementioned 3% adjustment. Hospitalization cost was calculated by multiplying total charge by the CCR. The costs were then adjusted for inflation to year 2000 dollars using the general Consumer Price Index. Cost per hospital day was calculated by dividing cost by LOS. Charges were missing for 9790 (1.72%) of hospitalizations. We were unable to establish a CCR for 4079 (0.72%) of the hospitalizations. As a result of a missing charge or CCR, cost was missing for 11635 (2.04%) of the hospitalizations, which were eliminated from the cost analyses.

Statistical Analysis

Summary statistics of patient and hospitalization characteristics were calculated. Statistical significance of the annual trend was assessed using the Mantel-Haenszel chi-square test for trend. We report composite data for 1993–1995 and 2003–2005, treating each as a single observation. Our first analysis presents trends in mortality rate, adjusted for the age (by decade) and gender composition of the reference year (1993) hospitalizations.

Previous research has shown a biased coding of certain comorbidities.[18] In particular, coding of six of the Elixhauser CIVs have paradoxically been associated with reduced mortality risk.[19] We therefore estimated univariate logistic regressions of mortality on these CIVs to ascertain potential for coding bias. Of these six, the three associated with a lower risk of mortality (depression, drug abuse, and obesity) were excluded from subsequent analyses.

Multivariate logistic regression was then performed, estimating the likelihood of death. Our primary outcome measure was the adjusted odds ratio (OR) of in-hospital death in each year relative to 1993. The primary analysis regressed survival on categorical variables for each year, age-sex by 10-year age categories, and 26 CIVs. To assess for the impact of changing admission and coding practices, this regression was repeated (a) excluding patients admitted from LTC facilities; and (b) after restricting patients in all years to a maximum of five total discharge diagnoses.

Since the trend toward a shorter LOS reduces the duration of observation, we also calculated the daily mortality rate – the proportion of patients still hospitalized who died on each day. Additionally, a multivariate Cox proportional-hazards model was used to estimate the trend in

mortality, accounting for the censoring that early discharge creates. The daily mortality rate became disproportionately higher among the 25% of hospitalizations greater than one week, likely reflecting selection based on poor health and/or severe disease. Because of this disproportionality, all patients were censored at a LOS of 7 days for the hazard model.

To analyze costs, we calculated the annual median hospitalization cost and median cost per hospital day. We also performed two generalized linear model (GLM) regressions to analyze cost trends, both of which specified cost as the dependent variable, using a gamma distribution and log link function.[20] Due to a non-random pattern of residuals in the highest-cost 1% of hospitalizations, this 1% was eliminated from the analyses. Both regressions included the same independent variables as the primary mortality regression described above. The second GLM regression additionally included LOS as an independent variable to ascertain how much of the cost trend might be attributable to changes in LOS.

All statistical analyses were performed using Statistical Analysis Software, version 9.1 (SAS; SAS Institute Inc., Cary, NC).

RESULTS

We identified 569,524 patients who met the coding criteria for CAP. As Table 1 illustrates, **comparison of hospitalization subsets in two periods shows that** mean LOS declined from 7.5 to 5.7 days, while the proportion of patients discharged to a SNF/ICF or with HHC increased. Figure 1 exhibits the trend in several common comorbidities.

Table 1 demonstrates that mortality rates declined across age-categories. Figure 2A shows the mortality trend, adjusted for age and gender, which declined from 8.9% to 4.1% ($P < 0.001$). Figure 2B demonstrates the results of the multivariate-adjusted logistic regressions (complete results in the appendix). The OR of death declined to 0.50 (95% CI 0.48–0.53) in 2005. The results of the regression excluding patients admitted from LTC facilities ($OR_{2005} = 0.50$) were very similar to the primary regression. After restricting all patients to a maximum of five diagnoses, the OR_{2005} was 0.51.

The daily mortality risk is shown in Figure 3, which demonstrates that the mortality rate on any given day early in the hospitalization is lower in 2004/2005 compared to 1993/1994. The hazard ratio of mortality in 2005 was 0.74 (95% CI 0.70–0.78), suggesting a 26% lower multivariate-adjusted risk of mortality, accounting for the censoring created by early discharge.

Figure 4 shows that, over the study period, median hospitalization costs **(based on 557,889 hospitalizations)** declined from $5473 to $4913, while median costs per hospital day increased from $868 to $1154. It also shows the results of the multivariate-adjusted GLM cost regressions, which calculate adjusted, mean predicted costs. The predicted mean cost of hospitalization in 2005 is $1017 less than in 1993. As is suggested by the increase in median per day costs, when also adjusted for LOS, the predicted cost of hospitalization in 2005 is $1200 higher than in 1993.

DISCUSSION

Studies have shown the benefit of several interventions in improving the outcomes of CAP patients.[21] Despite this, our study is the first to assess trends in outcomes and costs over many

years using a large, nationally-representative database. Until fairly recently, the mortality risk associated with CAP was high. For reference, a 1982 Lancet report studying CAP patients (mean age 51) showed an in-hospital mortality rate of 15%.[22] A prospective study conducted from 1981 to 1987 showed a mortality rate of 28.6% among elderly hospitalized pneumonia patients.[23] Our analysis reveals a marked mortality reduction over time among a large sample of hospitalizations for CAP. Further, adjusted costs were lower at the end of the period than at the beginning. **These findings support the assertion that** pneumonia care is a case of improved productivity – better health at lower spending.

This study shows improvement in outcomes for pneumonia patients, as an increasing incidence makes this a public health priority. We also demonstrate that outcomes of CAP patients have improved despite an increasing comorbidity burden. Moreover, this improvement occurred during a time when a trend toward outpatient treatment might make hospitalized patients sicker in ways we cannot measure.

Several factors may explain the mortality reduction. Improvements in critical care have likely impacted pneumonia outcomes.[24, 25] PV has little effect on incidence, but decreases mortality through reduced rates of bacteremia and invasive pneumococcal disease.[8, 26, 27] IV has also been associated with a lower mortality among hospitalized CAP patients.[9] The Behavior Risk Factor Surveillance System reports that from 1993 to 2005, the percent of elderly adults who received PV and IV increased from 27.8% to 65.9% and from 50.9% to 65.7%, respectively.[28] Guideline-concordant, combination antibiotic therapy reduces mortality compared to monotherapy.[6, 29, 30] One study found that three broad-spectrum antibiotic regimens reduced mortality with hazard

ratios of 0.64 to 0.71.[31] Data from the early 1990s showed that only 54-64% of CAP patients received broad-spectrum antibiotics.[32, 33] Recent Community-Acquired Pneumonia Organization data showed that 88% received such therapy.[34] Although less likely to explain the mortality trend, early antibiotics and obtaining blood cultures have also been associated with reduced mortality.[7] Since NIS data does not include specific antibiotic information or patients' vaccination history, we cannot definitively determine the reasons for the identified trends. However, based on the referenced literature, we posit that more widespread use of these interventions has achieved substantial benefit among CAP patients.

Our findings on hospitalization costs are consistent with other literature showing that reduced LOS with higher daily costs are keeping hospitalization costs relatively constant over time.[35, 36] Over the study period, our data revealed a 32% increase in median daily costs. Our calculated median hospitalization and daily costs in the reference year 1993 of $5473 and $868, respectively, are similar to the $5942 and $836 found in the Pneumonia Patient Outcomes Research Team cohort study, conducted from 1991 through 1994.[37] This concordance suggests that the AHRQ-recommended cost imputation methods produced accurate results. Greatly reduced mortality at a lower cost suggests a productivity improvement and increase in the value of CAP-related expenditures over time. Furthermore, Our GLM regression results suggest that LOS has been the major identifiable mechanism by which costs have declined.

This study is limited to capturing in-hospital mortality, without 30-day mortality or readmission rates. With a decreased LOS, more patients were discharged to other facilities. Reduced LOS might artifactually decrease the in-hospital death rate among those patients

discharged early. It is therefore possible that more deaths occurred after discharge in recent years. However, the hazard model, which accounted for the censoring of early discharge, also shows a large improvement over time. We also show a marked reduction in the daily mortality risk early in the hospitalization, during which time comparisons would be less sensitive to changing discharge practices. Moreover, one study showed that readmission rates, **as well as post-discharge and** 30-day mortality rates, did not differ among hospitals despite significant variation in LOS.[38] **While this study evaluated the relationship of mortality rates and cross-sectional (rather than longitudinal) variation in LOS,** it does suggest that physicians' judgment about criteria for early discharge does not compromise post-discharge outcomes. Our study is also limited by the absence of physiologic indicators necessary to calculate a pneumonia severity index (PSI). However, it is likely that the patients admitted in recent years are, on average, physiologically sicker than those admitted in early years. Therefore, we believe that inclusion of a PSI would not diminish the demonstrated improvement. It is also possible that a portion of the increased frequency of comorbid conditions is due to changes in coding practices and the increased number of coding fields. However, this finding is consistent with other studies of hospitalized pneumonia patients.[1] Demographics and improved survivorship of patients with other illnesses, such as cardiac disease, may be contributing to the increasing hospitalization rates for CAP. Furthermore, much of the improved survival we demonstrate was already evident before adjusting for comorbidities.

While we examine the costs of hospital care for CAP, we do not account for the costs of post-acute care. However, research suggests that site-of-care substitution results in post-acute care costs much less than the savings achieved through reduced LOS.[36] Another study showed that

the mean post-acute care costs for the 40% of hospitalized pneumonia patients who received any post-acute care was $1100.[15] In our study, the percentage of patients who were either discharged to a SNF/ICF or with HHC increased from 27.7% in the early years to 34.6% in recent years. Extrapolating this 6.9% increase to our study population with a mean $1100 per discharge would increase the average cost per hospitalization by only $76, an amount which would not change our conclusions. Moreover, post-acute care has been shown to decrease the total costs of an episode of illness by reducing the readmission rate.[39] It is therefore possible that, despite additional direct costs, greater use of post-acute care would decrease the total cost of a CAP episode. **While we do not know with certainty the effect that site-of-care substitution would have on cost trends, we believe that our analysis provides qualified evidence of improved productivity.**

In sum, while numerous studies have shown the benefit of several interventions in improving pneumonia outcomes, ours is the first study to demonstrate a reduction in mortality risk over time based on a large, national dataset. Caregivers should be encouraged by our study results, which suggest that their efforts have greatly decreased the risk of mortality posed by the "Captain of the Men of Death."

Additional Information: The appendix is available at http://journals.lww.com/lww-medicalcare/pages/default.aspx

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Figure Legends

Figure 1. Selected comorbidities of patients hospitalized for community-acquired pneumonia. Error bars indicate 95% confidence intervals. CHF denotes congestive heart failure; DM denotes diabetes mellitus.

Figure 2. Mortality trends adjusted for age and sex (A) and multivariable-adjusted odds ratio of death relative to the reference year 1993 (B). The multivariate model is adjusted for age, sex, and comorbid conditions. Error bars indicate 95% confidence intervals. LTC denotes long term care.

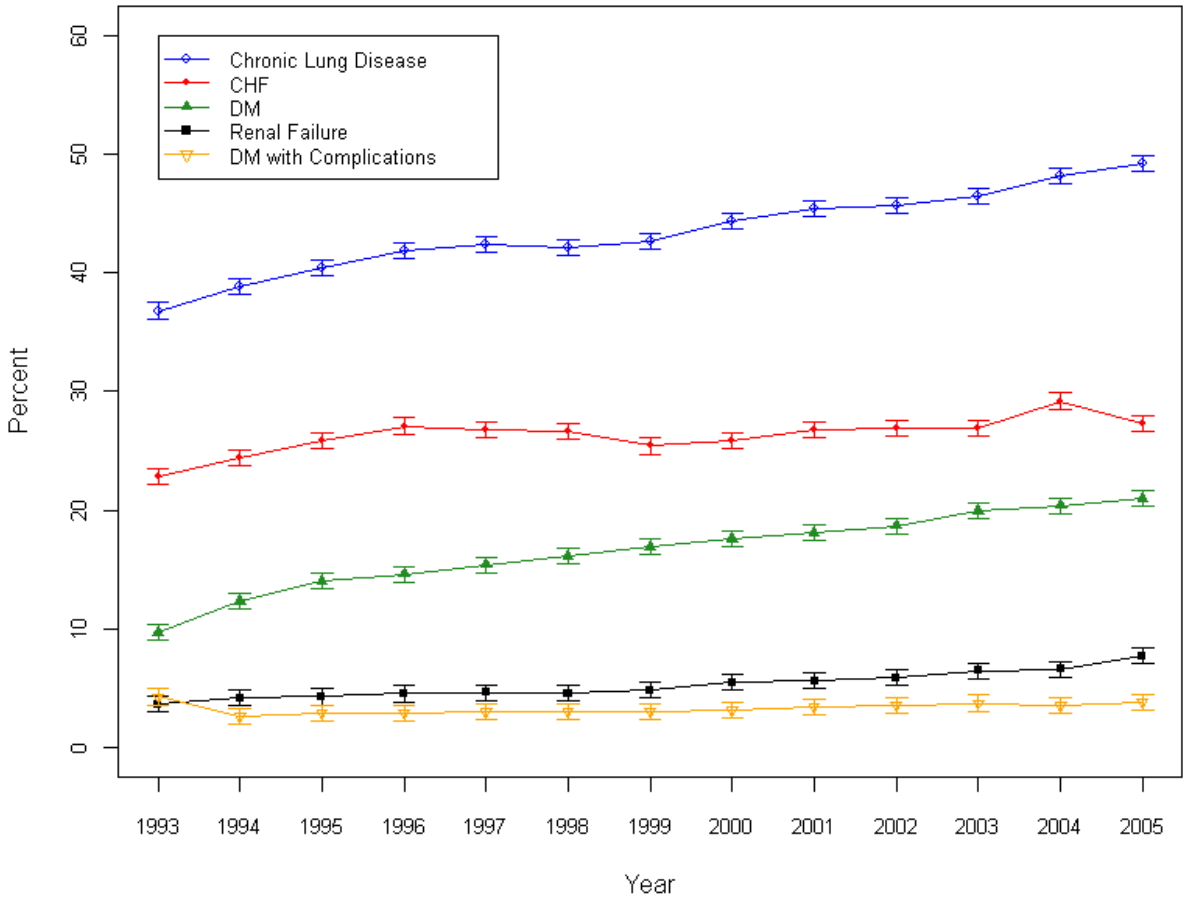
Figure 3. Daily mortality rates for 1993/1994 and 2004/2005 among patients still hospitalized on each hospital day. Error bars indicate 95% confidence intervals.

Figure 4. Trends in median hospitalization costs, total and per hospital day. The trend in predicted mean costs is based on a generalized linear model that specified cost as the dependent variable and age, sex, and comorbid conditions as covariates. One model also included length of stay (LOS).

TABLE 1. Patient and Hospitalization Characteristics in Two Selected Periods among Patients Hospitalized for Community-Acquired Pneumonia

	1993 – 1995 (n = 104,491)		2003 – 2005 (n = 277,916)	P
Age, by category (years)				
18 – 29 (%)	4,371 (4.2)		7,346 (2.6)	<.001
30 – 39 (%)	7,562 (7.2)		10,859 (3.9)	
40 – 49 (%)	7,589 (7.3)		21,431 (7.7)	
50 – 59 (%)	8,771 (8.4)		31,516 (11.3)	
60 – 69 (%)	16,278 (15.6)		44,176 (15.9)	
70 – 79 (%)	26,848 (25.7)		66,886 (24.1)	
80 – 89 (%)	25,290 (24.2)		71,990 (25.9)	
90 – 99 (%)	7,514 (7.2)		22,918 (8.2)	
100 + (%)	268 (0.3)		794 (0.3)	
Female, n (%)	50,434 (48.3)		148,426 (53.4)	<.001
Mean Length of Stay, Days	7.5		5.7	<.001
Admitted from long-term care facility, n (%)	4,598 (4.4)		6,114 (2.2)	<.001
Discharged to skilled nursing or other facility, n (%)	19,644 (18.8)		64,754 (23.3)	<.001
Discharge with home health care, n (%)	9,299 (8.9)		31,405 (11.3)	<.001
Mortality, overall, n (%)	8,827 (8.4)		13,133 (4.7)	<.001
Mortality, by age category				
18 – 29 (%)	65 (1.5)		88 (1.2)	
30 – 39 (%)	241 (3.2)		114 (1.0)	
40 – 49 (%)	296 (3.9)		354 (1.7)	
50 – 59 (%)	444 (5.1)		800 (2.5)	
60 – 69 (%)	1,069 (6.6)		1,444 (3.3)	
70 – 79 (%)	2,329 (8.7)		3,118 (4.7)	
80 – 89 (%)	3,127 (12.4)		4,926 (6.8)	
90 – 99 (%)	1,209 (16.1)		2,197 (9.6)	
100 + (%)	47 (17.5)		92 (11.6)	

Figure 1. Comorbidities of Patients Hospitalized for Community-Acquired Pneumonia



Error bars indicate 95% confidence intervals. CHF denotes congestive heart failure; DM denotes diabetes
mellitus.

Figure 2. Mortality Trends

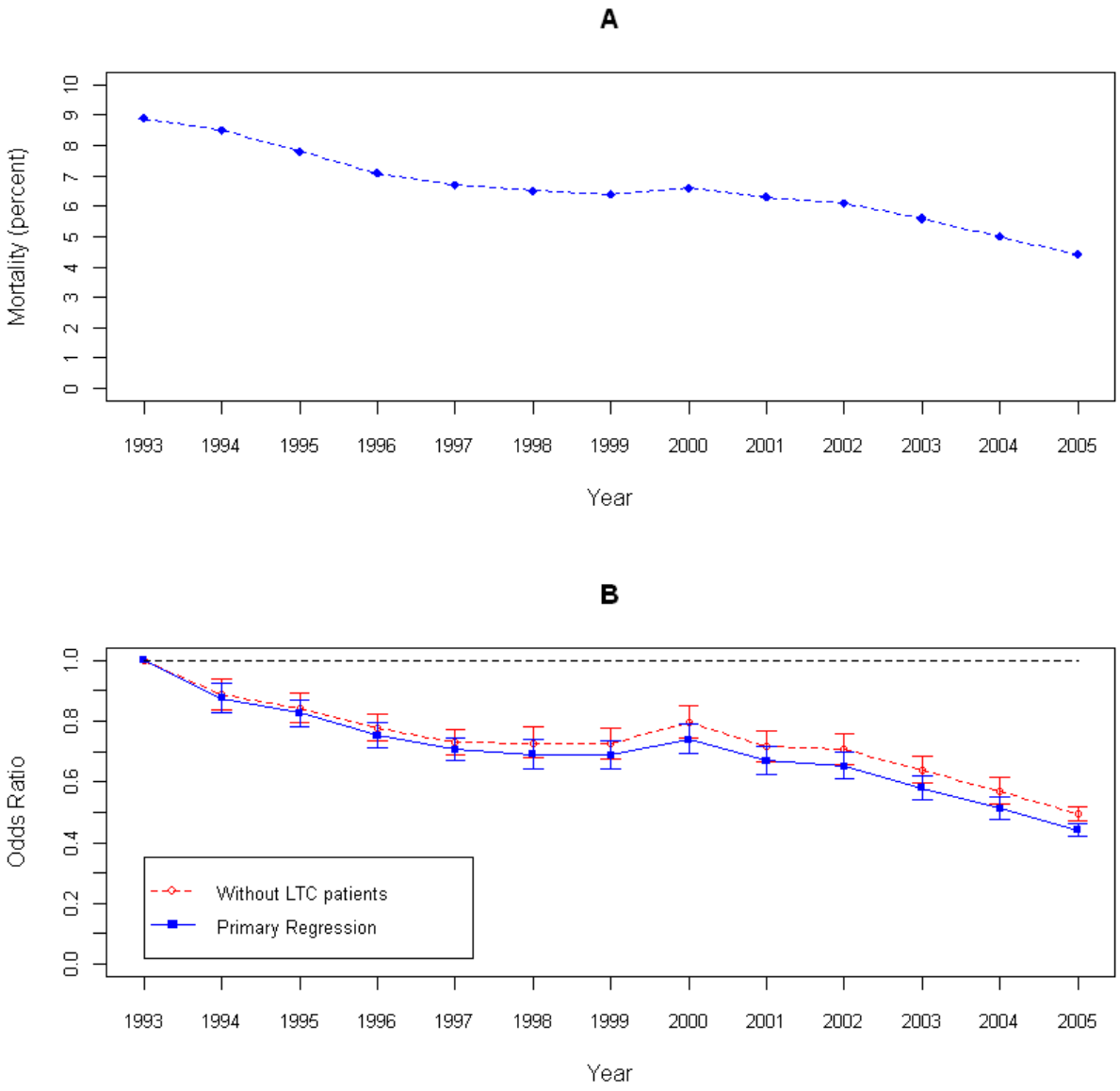


Figure 3. Daily Mortality Rate

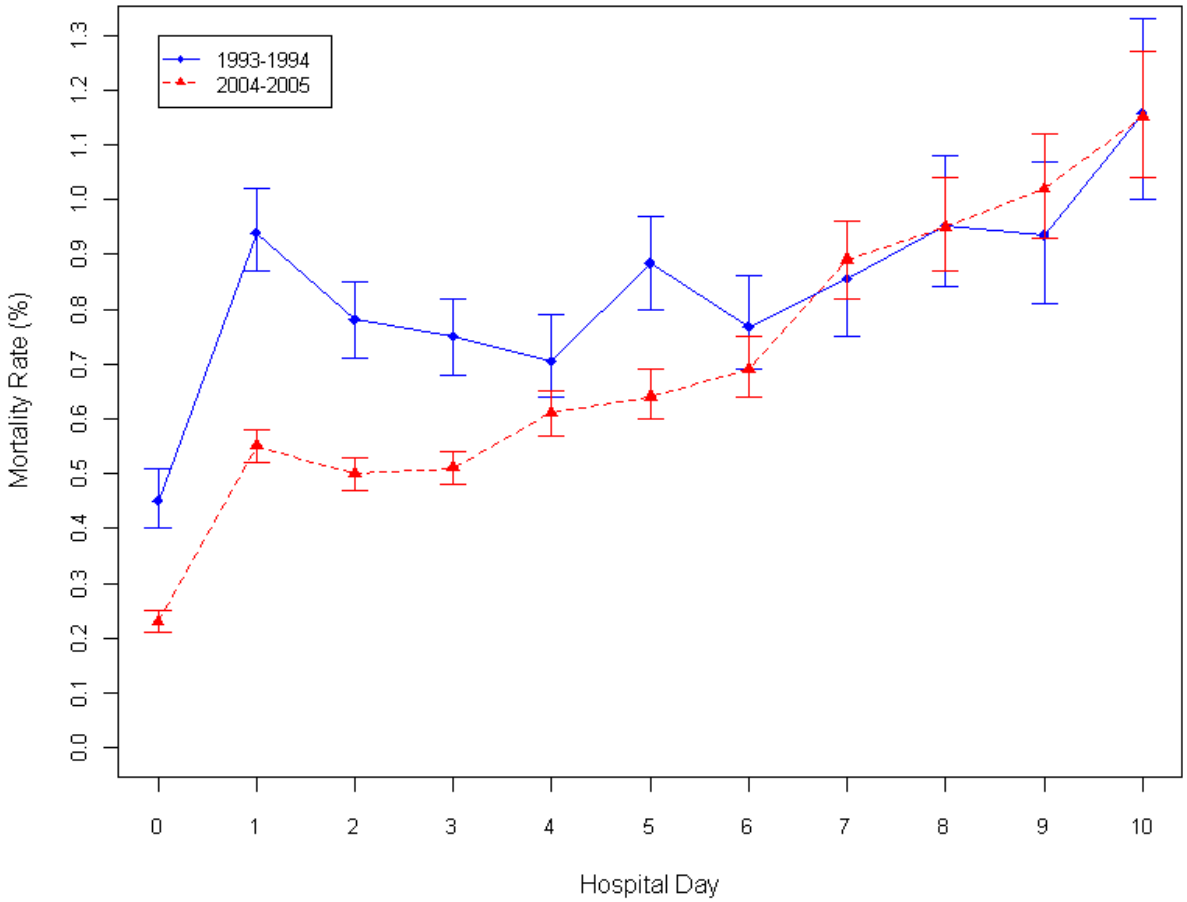


Figure 4. Hospitalization Costs