Temporal trends in critical care outcomes in United States minority serving hospitals

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At a glance: Minorities face a wide range of health disparities that extend into the Intensive Care unit (ICU). Whether hospitals that predominantly care for minority patients have evidenced the same improvements in critical care outcomes as non-minority hospitals has not been previously investigated. Accordingly, we examined the temporal trends of ICU mortality and lengths of stay in minority and non-minority serving hospitals from 2006 to 2016 in over 200 hospitals from across the United States. We find minority serving hospitals have had significantly less temporal improvement in mortality and length of stay than non-minority hospitals. This observation is most apparent for African American patients, who have had no meaningful decrease in mortality or lengths of stay when hospitalized in a minority serving hospital. Our data highlights the continued disparities facing minorities and minority serving hospitals in the United States.

Conception and design: JD

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Abstract

Context: Whether critical care improvements over the last ten years extend to all hospitals has not been described.

Objective: To examine the temporal trends of critical care outcomes in minority and non-minority serving hospitals.

Design: Inception cohort of critically ill patients.

Measurements: Using the Philips Health Care electronic Intensive Care Unit Research Institute Database, we identified minority-serving hospitals as those with an African American or Hispanic Intensive Care Unit (ICU) census more than twice its regional mean.

Participants: Almost 1.1 million critically ill patients amongst 208 ICUs across the United States admitted between 2006 and 2016.

Main outcome: Adjusted hospital mortality (primary) and length of hospitalization (secondary).

Results: Large pluralities of African Americans (25%, n=27,242) and Hispanics (48%, n=26,743) were cared for in minority serving hospitals, compared to only 5.2% (n=42,941) of whites. Over the last ten years, while the risk of critical illness mortality steadily decreased by 2% per year (95%CI 0.97-0.98) in non-minority hospitals, outcomes within minority-serving hospitals did not improve comparably. This disparity in temporal trends was particularly noticeable amongst African Americans, where each additional calendar year was associated with a 3%(95%CI 0.96-0.97) lower adjusted critical illness mortality within a non-minority hospital, but no change within minority-serving hospitals (HR 0.99, 95%CI 0.97-1.01). Similarly while ICU and hospital lengths of stay decreased by 0.08(95%CI -0.08,-0.07) and 0.16(95%CI-0.16,-0.15)days per additional calendar year, respectively, in non-minority serving hospitals, there was little temporal change for African Americans in minority serving hospitals.

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84 ***Conclusion***: Critically ill African Americans are disproportionately cared for in minority-serving hospitals,

85 which have shown significantly less improvement than non-minority hospitals over the last ten years.

Introduction

Health disparities continue to plague the United States medical system[1]. Despite higher rates of comorbidities[2], minorities have less access to preventative medicine[3–6], seeking care in lower-performance hospitals with higher complication[7,8], readmission[9], and mortality rates [10–13]. While the higher acuity and resource utilization of critical illness might seem immune to such disparities, racial differences in the intensive care unit(ICU) have similarly been described[14–18].

Accordingly, we examined whether improvements in critical care outcomes over the last decade [19–22] extend to minority serving hospitals. Using a large repository of almost 1.1 million ICU admissions from hospitals across the United States[23–25], we describe the temporal trends of critical illness outcomes according to hospital minority composition and whether these trends differed by ethnicity.

Methods

Data Source

Phillips Healthcare, a major vendor of ICU equipment and services, provides a telehealth ICU platform to over 300 hospitals across the United States. Data from participating hospitals is anonymously curated in the electronic Intensive Care Unit Research Institute Database (eICU-RI), a collaborative partnership between Philips Healthcare and the Laboratory of Computational Physiology at Massachusetts Institute of Technology[23–26]. It contains high-resolution patient data including demographics, vital signs, laboratory tests, illness severity scores, fluid intake and outputs, and diagnostic coding from patients admitted between 2003 and 2016. Participating hospitals trained clinicians to use the Philips platform, using primary data entry and drop-down boxes to adjudicate patient information and diagnoses, with direct synchronization with laboratory and clinical data.

The most up-to-date formulation of the eICU-RI contains 1.7 million unique first critical illness hospitalizations from 301 hospitals. Missing data included hospital regional location (n= 430,137) and

Acute Physiology and Chronic Health Evaluation (APACHE) IV severity of illness scoring (n=104,041). We excluded those admitted prior to 2006 (n=30,207) due to low participation and unreliability of data entry, leaving 1,088,109 patients. Of these, 48,514 lacked documentation of length of critical stay, leaving a cohort of 1,039,595 for primary analysis.

Exposure

We used 2010 United States Census data to determine the African American and Hispanic regional means and defined minority-serving hospitals as those with a greater than two-fold African American or Hispanic ICU census than the corresponding regional mean. The cutpoints for African American and Hispanics were 11.30% and 7.0% in the Midwest, 13% and 12.6% in the Northeast, 20.1% and 15.9% in the South and 5.7% and 28.6% in the West, respectively. [28] As an alternate definition, we defined minority-serving hospitals as those with a greater than 25% African American or Hispanic ICU patient census[11].

Outcomes

Our primary outcome was death during critical illness hospitalization. The secondary outcomes were ICU and hospital lengths of stay.

Categorization of trends

We examined year of admission as a categorical (i.e., as individual two-year groups) and continuous variable.

Variables

Basic demographics included age, gender, and ethnicity. Ethnicity was self-reported as white, African American, Hispanic, Asian, Native American, other, or unknown. Admission diagnoses were adjudicated by trained clinicians within the first 24 hours of ICU admission as part of the APACHE IV score system[29], and were categorized into the fifteen most common clinical categories, including sepsis, myocardial infarction/angina, trauma, gastrointestinal bleed, arrhythmia, drug/alcohol complications,

cerebrovascular accident, coronary artery bypass grafting, pneumonia, malignancy related, congestive heart failure, cardiac arrest, angina, diabetes related, intracranial bleed, other and unknown. The admission APACHE IV score, obtained within 24 hours of ICU admission, was used to quantify severity of illness. The Charlson comorbidity scoring system was used to describe preexisting illness burden[30]. ICU unit type (medical, medical surgical, surgical, cardiac, cardiothoracic, and neurological) was included as a series of indicator variables.

Analysis

Baseline characteristics were presented as percentages for categorical variables and mean and standard deviation for continuous variables by hospital minority composition. We used Cox proportional hazards model to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the associations between categorical year of admission and mortality. Time to event was defined as the length of stay between ICU admission and date of death or censoring. Patients who were discharged were censored at that time. The models were adjusted for age, sex, ethnicity (white, African American, Hispanic, or other), unit type (categorical), admission diagnosis (categorical), APACHE IV severity of illness and Charlson comorbidity scores (continuous), and year of admission (categorical; 2006-2008 as the reference group). We used multiplicative interactions to determine whether the effect of admission year on mortality differed according to hospital minority composition, and explored whether these findings were consistent across ethnicity.

In secondary analyses, we defined minority-serving hospitals as those with a >25% African American or Hispanic ICU census and conducted survival analyses as in our primary analysis. Second, we applied generalized estimating equations (GEE) with Poisson error distribution, log link function, and exchangeable covariance structure to examine the associations between categorical admission year and mortality in those hospitals with greater than 500 admissions. This approach allowed us to account for

within-hospital correlation. Third, to account for hospital participation, we examined our primary analysis in those hospitals that had consistent participation in four consecutive time periods.

As secondary endpoints, we describe ICU and critical illness hospitalization lengths of stay according to minority hospital composition. Using standard least squares regression, including all variables from the primary analysis and an indicator for hospital mortality, we describe the adjusted differences in lengths of stay in minority-serving and non-minority hospitals and how these trends have changed over time.

To determine whether there were differences in critical illness resource utilization across hospitals, we examined the delay to ICU transfer in those patients admitted directly from the emergency deparment[31]. Using all variables above, and an indicator variable for hospital mortality, we describe whether the delay differed by hospital composition and how these trends have changed over time.

All analyses were performed using JMP Pro 12 and PROC PHREG and PROC GENMOD in SAS 9.4 (both produced by SAS Institute, Cary, NC).

Results

Usage and characteristics of minority serving hospitals

Of almost 1.1 million critically ill patients, 10%(n=109,022) were cared for in one of 14(7% of sampled hospitals) minority serving hospitals. There was significant ethnic variation in usage of such hospitals, with 25%(n=27,242) of African American and 48%(n=26,743) of Hispanic patients receiving critical care in a minority serving hospital, compared to 5.2%(n=42,941) of white patients. Patients in minority serving hospitals tended to be younger, with a lower comorbidity burden(Table 1), yet a higher level of illness severity on ICU presentation. Minority serving hospitals had a higher relative percentage of ICU admissions for trauma, myocardial infarction, and heart failure, and a lower percentage for sepsis and drug and alcohol complications, than non-minority hospitals. Hospital mortality proportions were

higher in minority than non-minority hospitals (10.5 vs 9.5%, p<0.001), consistently across ethnic groupings.

Temporal trends in critical care mortality

While the incidence of critical illness mortality (Figure 1) and adjusted mortality (Table 2) steadily decreased from 2006 to 2016, the trends differed between minority and non-minority serving hospitals (multiplicative interaction between calendar year and minority-serving hospital p value <0.001). A steady decline in critical illness mortality (HR 0.98, 95%CI 0.97-0.98 per additional calendar year) was observed in non-minority hospitals, but not in minority serving hospitals (Table 2, supplemental table 1).

This temporal inequality was most apparent amongst African American patients (multiplicative interaction between calendar year and minority-serving hospital p values 0.02, 0.07, and 0.04 amongst African American, Hispanic, and white patients, respectively), where each additional calendar year was associated with 3% lower adjusted mortality (HR 0.97, 95%CI 0.96-0.97) in non-minority hospitals, compared to no change in minority-serving hospitals (HR 0.99, 95%CI 0.97-1.01)(Figure 2).

Sensitivity analyses of mortality

Using a threshold of more than a 25% African American or Hispanic ICU census to define a minority hospital resulted in 26 minority-serving hospitals serving 177,186 patients. Patients within these hospitals had higher mortality rates and similarly less temporal improvement (multiplicative interaction between each additional calendar year and minority-serving hospital p value 0.05) than those in non-minority hospitals (Table 3). Analyses that accounted for within-hospital correlation and participation resulted in similar findings.

Temporal trends in ICU and hospital lengths of stay

The lengths of ICU stay and critical illness hospitalization were higher among minority than non-minority serving hospitals(3.1±3.9 and 7.3±6.9 days compared to 2.9±3.6 and 6.4±6.2 days, respectively), a

difference that remained in an adjusted analysis that included hospital mortality [0.03(95%CI 0.02-0.04, p<0.001) and 0.21(95%CI 0.20-0.23, p<0.001) days longer ICU and hospital stays in minority serving hospitals, respectively]. ICU and hospital lengths of stay steadily decreased in non-minority serving hospitals [-0.08(95%CI -0.08,-0.07, p<0.001) and -0.16(95%CI-0.16,-0.15,p<0.001) days per additional calendar year, respectively], but significantly less so amongst minority serving hospitals (multiplicative interaction between minority hospital and admission year p values <0.001 for both ICU and hospital lengths of stay), remaining essentially constant from 2011 to 2016(Figure 3, Table 3). This temporal disparity was most apparent in African American patients, for whom length of stay decreased in non-minority hospitals, but not in minority serving hospitals (Table 4).

Temporal trends in delay to ICU transfer in patients admitted from the emergency department

Amongst 567,325 ICU admissions from the emergency department, the mean± SD delay until ICU admission was 3.9±16.3 hours among non-minority hospitals and 5.9± 19.4 hours among minority-serving hospitals (p<0.001). Over the last ten years, the adjusted delay decreased by 7.6 minutes (95%CI -8.66 to -6.51, p<0.001) per additional calendar year in non-minority hospitals, yet had little change (1.0 minutes; 95%CI-2.62 to 4.67, p=0.58) in minority-serving hospitals.

Discussion

In our sampling of approximately 200 hospitals across the United States, almost a third of critically ill African American and half of critically ill Hispanic patients received critical care in just 7% of surveyed hospitals. These minority-serving hospitals showed significantly less decline in critical illness mortality and length of stay over the last decade, compared to non-minority hospitals. While this inequality was consistent across ethnicities, it was most pronounced amongst African Americans, in whom we observed no temporal improvement in critical care mortality or reduction in length of stay during this period.

Minority serving hospitals tended to care for younger patients, with a lower overall burden of disease comorbidity, yet with a paradoxically higher severity of illness severity and mortality. Accordingly, it is difficult to determine whether our findings reflect caring for an increasingly disadvantaged population or differences in hospital resource utilization. As a proxy for hospital practice patterns, we examined the delay to ICU admission for those patients admitted through the emergency department, a clinically important indicator [31–34]. We found that minority-serving hospitals had significantly longer delays with little temporal improvement, while the adjusted delay to ICU admission decreased by almost eight minutes per year in non-minority hospitals.

Regardless of how much of the increased mortality risk is due to patient or hospital-specific issues, the high minority usage of these hospitals highlights the obstacles facing African Americans in the United States. The "neighborhood effect", whereby location of residence has a profound effect on outcomes[35–39], highlights the socioeconomic barriers to achieving equitable health care access, compounded by differences in practice patterns and resource utilization that extend into the ICU [40–42]. From the perspective of health care delivery, recognizing the challenges facing minority-serving hospitals is particularly important in the current "pay for performance" reimbursement paradigm[43] so as not to unfairly penalize the most vulnerable hospitals[44]. Our data provides clinical context for this concern, and underscores the need for additional support for minority-serving hospitals to ensure they have the appropriate resources to meet their strenuous clinical demand.

Our analysis has several notable limitations. Confounding due to either admission or discharge bias is possible, particularly since minority patients tend to receive more intensive therapy and testing towards end of life. Whether the ethnic distributions in the ICU were similar to those of the hospital were not known. In addition, how representative hospitals that choose to use the Phillips platform are is not known, and important patient characteristics, such as income, insurance type, and lifestyle choices, as

well as hospital information, were not available. Finally, using more granular population census definitions, such as county codes, could improve the precision of minority-hospital definitions. However, we examined two different definitions of minority hospitals, with similar results, and our primary findings were consistent through a range of sensitivity analyses and statistical approaches. Despite these limitations, the sheer size and granularity of this dataset are an important strength, providing a unique snapshot of modern American critical care over the last ten years.

Conclusion

A large proportion of minority patients receive critical illness care in a small number of minority-serving hospitals, which over the last ten years, have not enjoyed the steady decrease in mortality and length of stay that non-minority hospitals have. Whether this reflects a more systemic disparity, whereby African Americans are more medically disadvantaged upon presentation, or differences in hospital care and resources, is not known, but regardless, this observation highlights the profound obstacles facing minorities and minority-serving hospitals.

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Table 1. Baseline patient and hospital characteristics. Percentages for categorical variables and mean(standard deviation) for continuous variables provided. Abbreviations; MI-myocardial infarction, CABG-coronary artery bypass grafting, CHF-congestive heart failure, CVA-cerebrovascular accident, APACHE IV – Acute Physiology and Chronic Health Evaluation IV. [1]Categorization of hospital size was missing in 46,579 patients.

Patient and hospital characteristics		
	Minority serving hospitals	Non minority hospitals
Number of patients	109,022	979,087
Number of hospitals	14	194
Age(years)	61.8(18.2)	62.8(17.6)
Female	46.5	45.8
Ethnicity/Race		
White	39.4	80.6
African American	25.0	8.6
Hispanic	24.5	3.0
Other/Unknown	11.1	7.8
ICU type		
Cardiac/cardiothoracic	27.9	22.5
Medical	14.7	15.7
Medical/surgical	48.7	55.4
Surgical	8.7	6.4
Academic	32.3	27.8
Hospital beds[1]		
>500	35.2	43.8
250-500	36.7	20.4
Charlson Comorbidity Index	3.4(2.7)	3.5(2.7)
APACHE IV	55.7(27.0)	53.4(25.5)
Admission diagnosis		
Sepsis	7.7	10.2
MI/Angina	9.3	8.0
CABG	3.8	3.9
CHF	3.7	3.0
Trauma	5.5	5.1
Drug and Alcohol related	2.6	4.4
CVA	3.6	4.0
Pneumonia	3.6	3.6
Intracranial bleed	2.6	1.6
Hospital characteristics		
Academic	28.6	6.7

Hospital beds		
>500	14.2	11.3
250 to <500	36.0	15.4
Hospital mortality	10.5	9.5

Table 2. Hazard ratio(95% CI) of critical illness mortality per admission year category provided, with 2006-08 considered as reference for all analyses. Adjusted for age, gender, ethnicity, unit type, admission diagnosis, Charlson comorbidity score, and illness severity. In addition, alternative definition of hospital minority composition, and analytic approaches to account for within hospital correlation and hospital participation, provided. Multiplicative interaction p value between indicator for minority serving hospitals and admission year (defined continuously) provided.

Adjusted hazard ratios for critical illness mortality according to admission year and hospital minority composition						
	Admission year					
	2006-08	2009-10	2011-12	2013-14	2015-16	Multiplicative interaction term p value
All hospitals	Ref.	0.86 0.84-0.89	0.82 0.80-0.84	0.81 0.79-0.82	0.80 0.78-0.82	-
Minority serving hospitals	Ref.	0.83 0.77-0.89	0.88 0.82-0.95	0.79 0.74-0.85	0.88 0.81-0.94	<0.001
Non-minority hospitals	Ref.	0.87 0.85-0.89	0.80 0.79-0.82	0.81 0.79-0.82	0.79 0.77-0.81	
Minority hospital defined as having greater than 25% African American or Hispanic census						
Minority serving hospitals	Ref.	0.85 0.80-0.90	0.83 0.78-0.87	0.79 0.75-0.83	0.85 0.80-0.90	0.05
Non-minority hospitals	Ref.	0.87 0.84-0.89	0.81 0.79-0.83	0.81 0.79-0.83	0.79 0.77-0.81	
GEE analysis in hospitals with >500 admissions to account for hospital correlation						
Minority serving hospitals	Ref.	0.94 0.92-0.95	0.93 0.91-0.95	0.90 0.88-0.93	0.94 0.91-0.97	0.05
Non-minority hospitals	Ref.	0.94 0.92-0.95	0.90 0.88-0.92	0.89 0.87-0.91	0.88 0.86-0.90	
Cox regression in hospitals with participation in four consecutive time periods						
Minority serving hospitals	Ref.	0.82 0.76-0.88	0.87 0.81-0.94	0.75 0.70-0.81	0.87 0.81-0.94	0.003
Non-minority hospitals	Ref.	0.87 0.85-0.89	0.81 0.79-0.83	0.82 0.80-0.84	0.80 0.77-0.82	

Table 3. Change in length of intensive care unit and critical illness hospital stay(days), relative to 2006-08, adjusted for age, gender, ethnicity, unit type, admission diagnosis, Charlson comorbidity score, illness severity, admission year category, and hospital mortality. Multiplicative interaction between indicator for minority serving hospitals and admission year (defined continuously) provided.

Adjusted change of intensive care unit and critical illness hospitalization lengths of stay from 2006 to 2016						
	Admission year					
	2006-08	2009-10	2011-12	2013-14	2015-16	Multiplicative interaction term p value
Adjusted change in ICU length of stay						
Minority serving hospitals	Ref.	-0.35 -0.43,-0.27	-0.48 -0.56,-0.40	-0.41 -0.49,-0.34	-0.44 -0.52,-0.36	<0.001
Non-minority hospitals	Ref.	-0.42 -0.45,-0.39	-0.56 -0.59,-0.53	-0.64 -0.66,-0.61	-0.67 -0.70,-0.65	
Adjusted change in hospital length of stay						
Minority serving hospitals	Ref.	-0.74 -0.91,-0.59	-1.12 -1.27,-0.96	-1.01 -1.17,-0.87	-0.98 -1.13,-0.81	<0.001
Non-minority hospitals	Ref.	-0.56 -0.63,-0.50	-0.90 -0.95,-0.85	-1.14 -1.18,-1.09	-1.37 -1.41,-1.32	

Table 4. Adjusted change(95%CI) per additional calendar year in the length(days) of ICU and critical illness hospitalization according to ethnicity. Adjusted for age, gender, ethnicity, unit type, admission diagnosis, Charlson comorbidity score, illness severity, admission year (defined continuously), and hospital mortality. Multiplicative interactions between indicator for minority serving hospitals and admission year (defined continuously) were <0.001 within each ethnic strata.

Adjusted change(days) in length of stay per additional calendar year according to ethnicity				
	ICU length of stay		Hospital length of stay	
	Minority serving hospital	Non-minority hospital	Minority serving hospital	Non-minority hospital
African American	-0.01 -0.02,0.01 p=0.46	-0.09 -0.10,-0.08 p<0.001	-0.03 -0.07,0.01 p=0.19	-0.21 -0.23,-0.20 p<0.001
Hispanic	-0.09 -0.10,-0.07 p<0.001	-0.06 -0.07,-0.04 p<0.001	-0.20 -0.23,-0.16 p<0.001	-0.12 -0.15,-0.09 p<0.001
White	-0.04 -0.05,-0.02 p<0.001	-0.08 -0.08,-0.07 p<0.001	-0.08 -0.11,-0.06 p<0.001	-0.16 -0.17,-0.16 p<0.001

Figure 1. Critical illness mortality(95%CI) in minority and non-minority serving hospitals from 2006-2016 in the United States (n=1,088,109). Trend p values for minority serving and non-minority hospitals were 0.002 and <0.001, respectively.

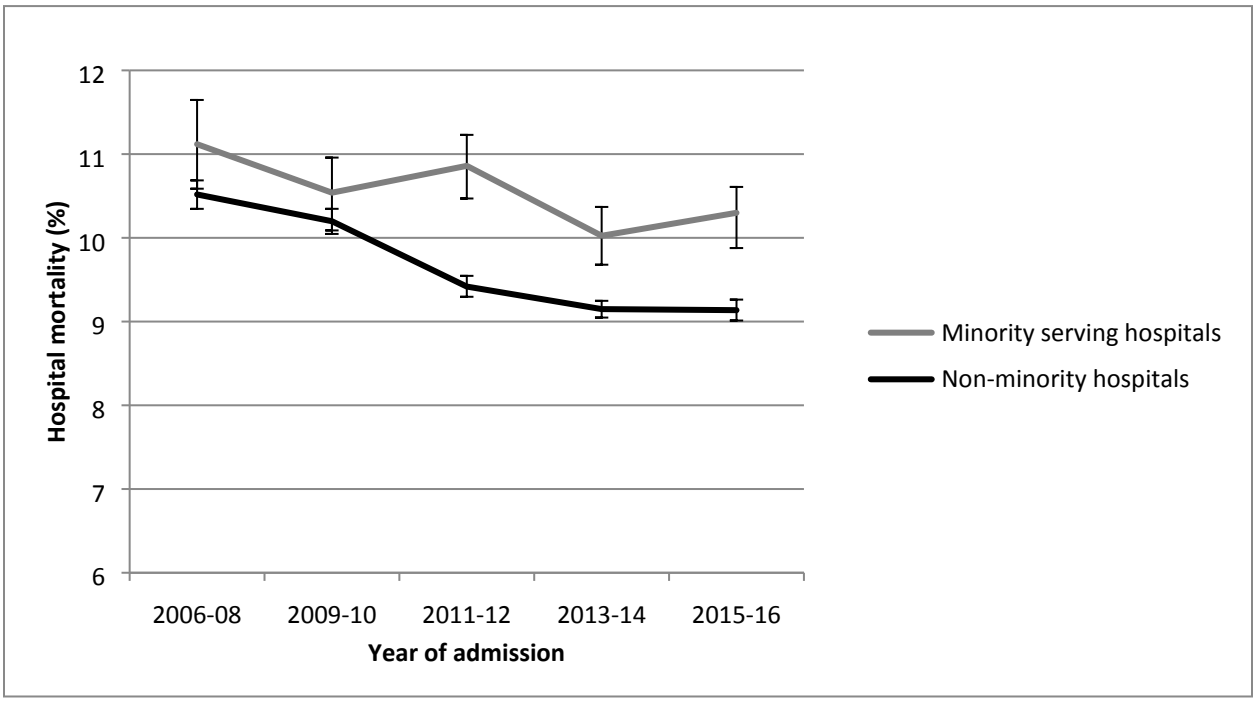


Figure 2. The adjusted hazard ratio (95% CI) of hospital mortality per additional calendar year of admission between 2006 and 2016, stratified by ethnicity. Adjusted for age, gender, unit type, admission diagnosis, Charlson comorbidity score, illness severity, and year of admission (defined continuously). Multiplicative interaction between calendar year and minority serving hospital p values 0.02, 0.07, and 0.04 amongst African American, Hispanic, and white patients, respectively. N=1,039,595 patients in 208 hospitals.

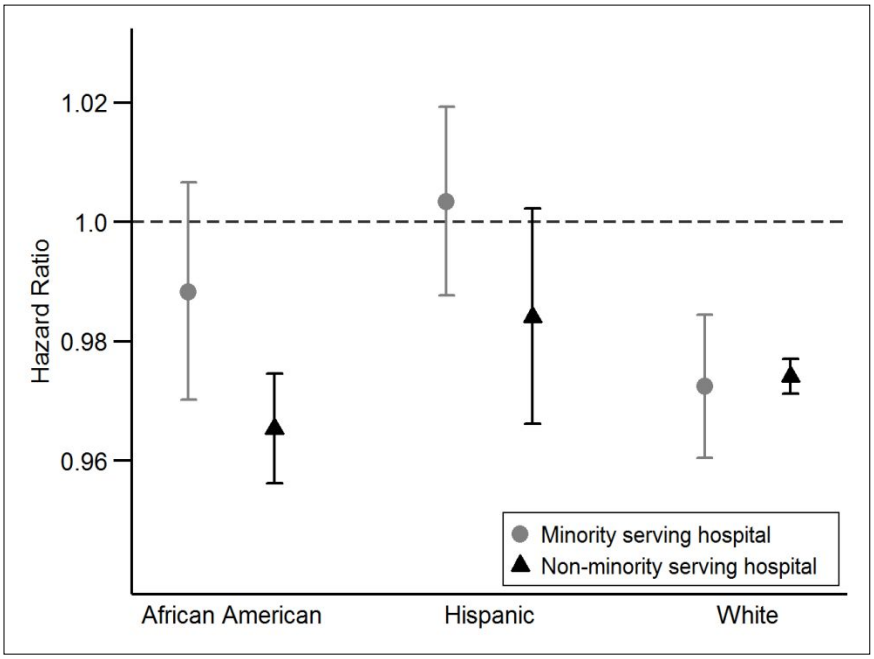
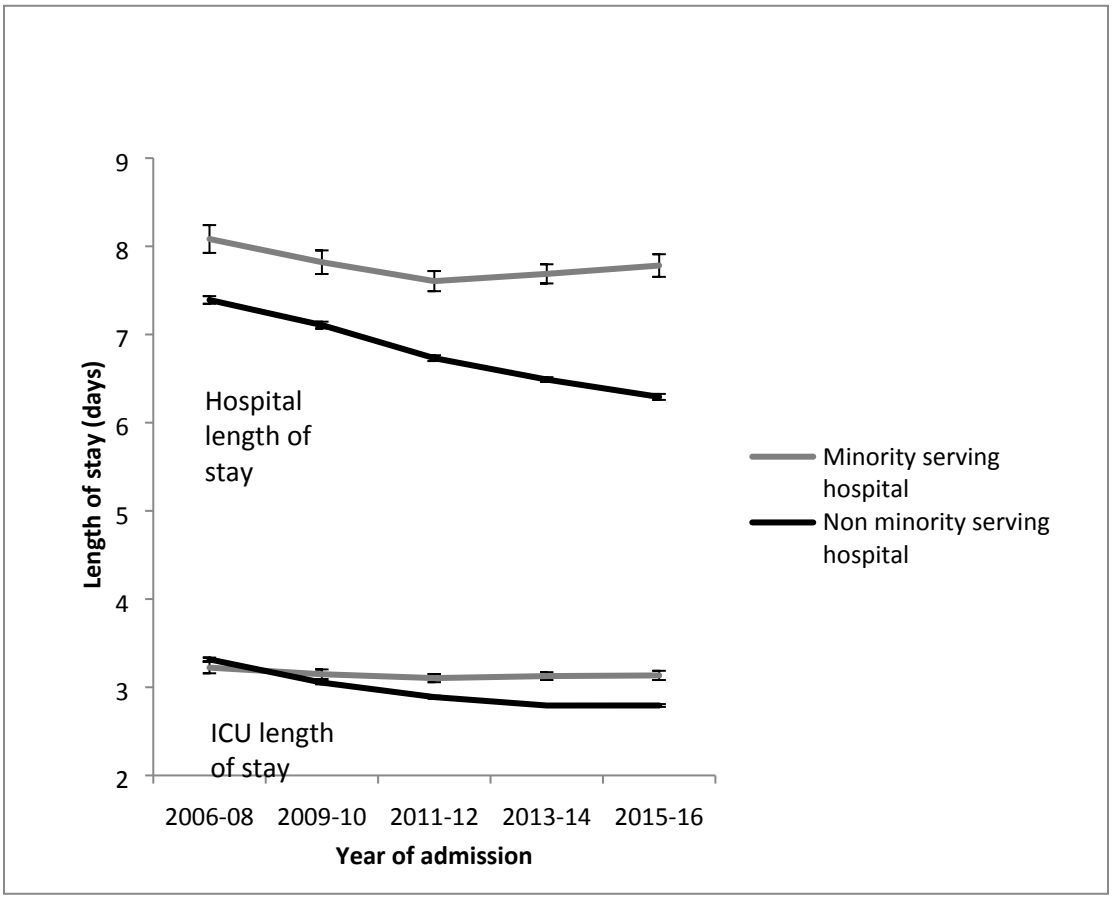


Figure 3. Temporal trends in hospital and ICU length of stay in minority and non-minority serving hospitals. Mean(95%CIs) lengths of stay according to year of admission provided. Trend p values all <0.001, except for ICU length of stay in minority serving hospitals (p=0.06).



Temporal trends of critical illness mortality rates according to hospital minority composition					
	2006-08	2009-10	2011-12	2013-14	2015-16
All hospitals	10.6	10.2	9.6	9.2	9.2
Minority Serving hospitals	11.1	10.5	10.9	10.0	10.3
African American	10.3	11.3	10.6	10.7	10.2
Hispanic	10.6	9.7	10.4	9.4	10.9
White	12.4	11.3	11.6	10.4	10.6
Non-minority serving hospitals	10.5	10.2	9.4	9.2	9.1
African American	10.1	10.1	8.8	8.3	8.4
Hispanic	7.3	8.1	7.0	7.6	8.0
White	10.7	10.3	9.5	9.3	9.3

Supplemental table I. Crude critical illness mortality rates (percentages) in minority and non-minority serving hospitals, stratified by ethnicity.