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A national analysis of the relationship between hospital factors and post-cardiac arrest mortality

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association between hospital factors (teaching status, location, size) and mortality, length of stay, and hospital charges. Analyses were performed using logistic regression. **Results:** A total of 109,739 patients were identified. In-hospital mortality was 70.6%. A 2% decrease in unadjusted mortality from 71.6% in 2000 to 69.6% in 2004 (OR 0.96, $P < 0.001$) was observed. Mortality was lower at teaching hospitals (OR 0.58, $P = 0.001$), urban hospitals (OR 0.63, $P = 0.004$), and large hospitals (OR 0.55, $P < 0.001$). **Conclusion:** Mortality after in-hospital cardiac arrest decreased over 5 years. Mortality was lower at urban, teaching, and large hospitals. There are implications for dissemination of best practices or regionalization of post-cardiac arrest care.

Abstract Purpose: We sought to generate national estimates for post-cardiac arrest mortality, to assess trends, and to identify hospital factors associated with survival. **Methods:** We used a national sample of US hospitals to identify patients resuscitated after cardiac arrest from 2000 to 2004 to describe the

Introduction

Despite advances in the understanding of the pathophysiology and epidemiology of cardiac arrest, survival from cardiac arrest remains low [1], and is associated with substantial morbidity [2]. There is little evidence to suggest that survival of patients initially resuscitated from cardiac arrest has changed over the past several decades [3, 4]. Historically, clinical research has focused on the pre-arrest and intra-arrest factors associated with return of spontaneous circulation (ROSC) after cardiac arrest [5–11].

Since 1991, the chain of survival has become an important framework for the continuum of cardiac arrest care [12]. Increasingly, post-arrest factors including hospital factors are being recognized as important in impacting survival rates and neurological recovery after resuscitation. Appropriate post-cardiac arrest care has been referred to as the fifth link in the chain of survival [13]. Post-arrest care has been demonstrated to significantly impact survival of patients who have ROSC after cardiac arrest. European studies have documented individual hospital variability in outcomes of patients admitted after

out-of-hospital cardiac arrest with mortality rates ranging from 41 to 86% [3, 5, 14]. Clinical trials of therapeutic hypothermia have demonstrated improved neurologic function and increased survival after out of hospital cardiac arrest [15, 16]. The proposed mechanisms of hypothermia and the delicate balance of benefit with side effects have been reviewed [17, 18]. However, formalized protocols to optimize post-cardiac arrest care have shown improved outcomes in individual institutions [19, 20].

In our present study we sought to generate nationally representative estimates for post-cardiac arrest mortality, to assess national trends over 5 years, and to assess variability in survival rates between institutions. We aimed to identify hospital level factors associated with survival of patients resuscitated after cardiac arrest. To perform this analysis, we used a discharge diagnosis of cardiac arrest within a nationally representative sample of all hospital discharges collected annually by the Agency for Healthcare Research and Quality (AHRQ).

Methods

Data

This retrospective analysis used data from the Nationwide Inpatient Sample (NIS) from 2000 to 2004. The NIS is the largest all payer, publicly available, inpatient care database available in the US, containing 5–8 million hospital stays from approximately 1,000 hospitals annually (994 in 2000, 986 in 2001, 995 in 2002, 994 in 2003, and 1,004 in 2005). The sample is conducted annually and is available from 1988 to 2004. The NIS provides patient level data on a stratified 20% sample of inpatient admissions at acute care hospitals in the United States and can be used to generate nationally representative estimates. Hospital characteristics [geographic region, location (urban or rural), ownership, teaching status, and bed size] are used to ensure that the sample is representative. Categorization by bed size is variable by region of the country, urbanicity, and teaching status of the hospital. Data available in the NIS include demographics, diagnoses, procedures, hospital characteristics, and discharge disposition. The

NIS is maintained by the Healthcare Cost and Utilization Project (HCUP) at the AHRQ. Further details are available at <http://www.hcup-us.ahrq.gov/nisoverview.jsp>. The study was approved by the Institutional Review Board at the University of Pennsylvania.

Patients

We identified all patients from 2000 to 2004 with a diagnosis of “cardiac arrest” using ICD-9 codes (427.5) ($N = 132,959$). The ICD-9 code for cardiac arrest can be generated through four mechanisms [21], and can be identified as the “primary diagnosis” or as a “secondary diagnosis” (Fig. 1). The “primary diagnosis” of cardiac arrest is appropriately assigned only to patients presenting to the emergency department (ED) in the state of cardiac arrest who have transient ROSC and die in the ED, or who survive to be admitted to the hospital but die before the etiology of the cardiac arrest is determined. This represented 6% of the overall sample ($N = 8,161$) and is not thought to be the population of interest.

The population of interest is those who were given a “secondary diagnosis” of cardiac arrest. Guidelines explain that this diagnosis is appropriately given when a patient has a cardiac arrest during the course of the hospitalization and is resuscitated, or when a patient presents to the ED in cardiac arrest with a discernable etiology and survives to be admitted to the hospital (Fig. 1). Thus, we do not differentiate between in-hospital and out-of-hospital arrest, but rather include patients who experience more than transient ROSC after cardiac arrest and exclude patients who do not have ROSC after their arrest.

Patients with a secondary diagnosis of cardiac arrest represented 94% of the overall sample ($N = 124,798$). Since our goal was to examine hospital factors related to post-cardiac arrest mortality, we included in our primary analysis only patients with a secondary diagnosis of cardiac arrest who were resuscitated and admitted more than transiently. In addition, we excluded other patients from our primary analysis including the following: (1) patients for whom hospital survival data were missing ($N = 226$), (2) patients who were discharged alive from the hospital

Fig. 1 Assignment of ICD-9 Code for Cardiac Arrest (427.5)

Primary Diagnosis	Secondary Diagnosis
<p>Patients presenting to the ED in the state of cardiac arrest who:</p> <ul style="list-style-type: none"> • Have only transient return of spontaneous circulation and die in the ED • Survive to be admitted to the hospital but die before the etiology of the cardiac arrest is determined 	<ul style="list-style-type: none"> • Patient has a cardiac arrest during the course of the hospitalization and is resuscitated • Patient presents to the ED in cardiac arrest with a discernable etiology and survives to be admitted to the hospital

in less than 24 h ($N = 2,906$), and (3) patients received in transfer from other acute care hospitals ($N = 9,107$). We compared our study population to patients with a principal ICD-9 diagnosis of cardiac arrest to examine differences between the groups. We compared our results with and without the exclusion of children (age <18) to determine if this altered the outcomes in any way.

Analysis

The primary outcome variable in our analysis was in-hospital mortality. Secondary outcome variables included hospital length of stay and total hospital charges. Demographic variables used in the analysis included race, gender, census region, age, and median household income by quartile for the patient's zip code. Hospital level variables included size of hospital (small vs. medium vs. large), teaching status of hospital (teaching vs. non-teaching), and location of the hospital (urban vs. rural). We could not stratify by procedures performed as we could not determine whether the procedure preceded or followed the patient's cardiac arrest.

Descriptive statistics were used in the analysis of demographics, length of stay, charges, hospital level factors, and procedures. Unadjusted analyses were performed using the chi square test, the Mann-Whitney U test, and the Student's t test. Logistic regression was used to evaluate hospital level factors hypothesized to be related to survival. The model evaluated death while controlling for year, age, gender, median income for zip code, and all hospital level factors (size, teaching status, location, and region of the hospital). We examined and excluded three way interactions from the model. We examined and included two-way interactions between hospital bed size and hospital teaching status, hospital bed size and hospital location, and hospital location and hospital teaching status. Conditional standardization was used to estimate the probability of survival for a standardized patient at various hospital types.

All data were managed with the Statistical Package for the Social Sciences (SPSS) version 11 (Chicago, IL), and analyses were performed with Stata 9 SE (College Station, Texas). The survey function of Stata and the sampling weights provided within the NIS were used to generate national estimates. Significant P values were defined as <0.05.

Results

Sample demographics

We identified 112,559 patients meeting the criteria. Only patients with complete data ($N = 109,739$) were included in our analysis. Given the sampling frame of the NIS,

we estimate that this represents the experience of 532,511 patients over the 5 years. The number of cases did not vary significantly over time ($P = 0.521$). The population had a median age of 72 [IQR 57–80] years. There were 2,023 patients under age 18. Removal of these patients did not change the point estimates and as a result they were left in the analysis. There was a significant decrease in the number of patients >60 years old over time (73% in 2000 vs. 68% in 2004, $P < 0.001$). Almost three quarters (70.41%) were white, and about half (53.11%) were male. Fewer than half of the patients (41.8%) were treated at teaching hospitals, and most (87.3%) were treated in urban areas. Almost two-thirds of patients (63.5%) were treated at large hospitals. All four census regions (Northeast, Midwest, South, and West) were represented, with the South being over-represented despite the sampling technique. Median length of hospital stay did not change over time for non-survivors (median = 3 days for 2000 and 2004, $P = 0.31$). There was a non-significant trend towards increased LOS for survivors (median = 10 for 2000 and 2004, $P = 0.06$). Hospital charges increased over time for patients who died (\$35,971 vs. \$53,435, $P < 0.001$) and for patients who survived (\$72,002 vs. \$106,190, $P < 0.001$). Characteristics of the sample are summarized in Table 1.

Table 1 Characteristics of the population

	<i>N</i> (%)
Cardiac arrest	109,739
Median age (years)	72 [IQR 57–80]
Mortality	79,464 (70.6)
Male	59,773 (53.1)
White	60,544 (70.4)
Black	13,652 (15.9)
Other	11,796 (13.7)
Teaching hospital	46,993 (41.8)
Small	11,858 (10.5)
Medium	29,254 (26.0)
Large	71,407 (63.5)
Urban	98,278 (87.3)
Northeast	18,304 (16.3)
Midwest	22,446 (19.9)
South	48,476 (43.1)
West	23,333 (20.7)
2000	22,150 (19.7)
2001	22,334 (19.8)
2002	22,401 (19.9)
2003	23,244 (20.7)
2004	22,430 (19.9)

The National Inpatient Sample (NIS) is a 20% stratified sample of all United States hospital discharges. Sampling weights provided by the NIS generate national estimates

Mortality

Overall in-hospital mortality was 70.6%. Each year of age was associated with greater mortality (OR 1.01, 95% CI 1.01–1.01, $P < 0.001$). Female gender was associated with higher mortality (OR 1.04, 95% CI 1.01–1.07, $P = 0.003$). There was a 2% decrease in unadjusted mortality from 71.6% in 2000 to 69.6% in 2004 ($P < 0.01$). This relationship was monotonic, and controlling for confounders including age, gender, and hospital factors, and this trend towards increased survival persisted (OR 0.96, 95% CI 0.94–0.98, $P < 0.001$) with adjusted probability of death decreasing from 72.9% in 2000 to 70.2% in 2004 (Fig. 2).

Hospital factors

In adjusted analyses (adjusted for age, gender, income, hospital factors, and the interactions between hospital factors), teaching status, hospital location, and hospital size were all associated with improved survival. Patients were more likely to survive if they were treated at a teaching hospital versus a non-teaching hospital (OR 0.58, 95% CI 0.42–0.79, $P = 0.001$). Patients were more likely to survive if they were treated at an urban hospital versus a rural hospital (OR 0.63, 95% CI 0.46–0.87, $P = 0.004$). No difference in mortality was observed for medium-sized hospital (OR 0.76, 95% CI 0.54–1.08, $P = 0.124$), but patients were more likely to survive if treated at large hospitals (OR 0.55, 95% CI 0.40–0.75, $P < 0.001$) (Table 2). The conditional probability of death by hospital type can be seen in Fig. 3. The probability of death, adjusting for other covariates, ranged from 0.58 at a large rural teaching hospital to 0.78 at a small rural non-teaching hospital.

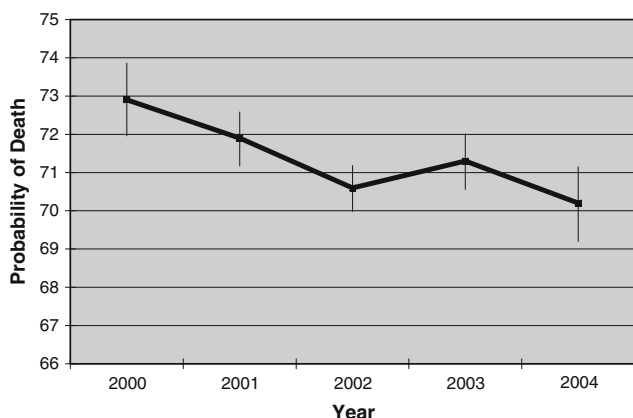


Fig. 2 Adjusted probability of death by year. Adjusted for age, gender, hospital location (urban/rural), hospital teaching status, hospital bed size (large, medium, small), median income for patient's zip code, and region of country in which hospital is located

Table 2 Mortality and hospital characteristics

	Mortality (%)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio ^a (95% CI)
Teaching status			
Non-teaching	72.3		Reference
Teaching	68.2	OR 0.86 (0.81–0.92) $P < 0.001$	OR 0.58 (0.42–0.79) $P = 0.001$
Location			
Rural	76.4		Reference
Urban	69.8	OR 0.75 (0.68–0.81) $P < 0.001$	OR 0.63 (0.46–0.87) $P = 0.004$
Hospital size			
Small	73.3		Reference
Medium	71.2	OR 0.89 (0.81–0.98) $P = 0.014$	OR 0.76 (0.54–1.08) $P = 0.124$
Large	69.9	OR 0.82 (0.75–0.89) $P < 0.001$	OR 0.55 (0.40–0.75) $P < 0.001$

^aEffect size is adjusted for age, gender, hospital location (urban/rural), hospital teaching status, hospital bed size (large, medium, small), median income for patient's zip code, and region of country in which hospital is located

Patients excluded from the primary analysis

We examined systematic differences between the primary study population and the population that was excluded by examining the relationship of the study population to patients who were transferred and patients who had a primary (rather than secondary) diagnosis of cardiac arrest. Patients who were transferred from another acute care hospital were younger (62.0 vs. 67.7, $P < 0.01$), more likely to be male (56.5 vs. 53.0%, $P < 0.01$), and less likely to die than patients admitted from the ED (59.7 vs. 70.1, $P < 0.05$).

After excluding transfers we compared patients with primary diagnosis of cardiac arrest to patients with secondary diagnosis of cardiac arrest. Patients with a primary diagnosis of cardiac arrest were slightly younger (67.0 vs. 67.5 years, $P = 0.02$), more likely to be female (53.1 vs. 50.3, $P < 0.001$), and more likely to die (84.3 vs. 70.6, $P < 0.001$) than patients with a secondary diagnosis of cardiac arrest. There were no significant differences with respect to race. In adjusted analyses, hospital factors were associated with mortality for patients with a secondary diagnosis of cardiac arrest, but not for those with a primary diagnosis of cardiac arrest.

Discussion

We present the first national estimate of in-hospital mortality of patients with a discharge diagnosis of cardiac arrest in the United States and identify hospital factors associated with mortality. We demonstrate a decrease in post-cardiac arrest mortality in the US over the last 5 years using an existing population level billing database as an epidemiologic tool. Although our absolute change in survival over 5 years was small, this mortality difference translates to an estimated 11,000 lives per year. Despite

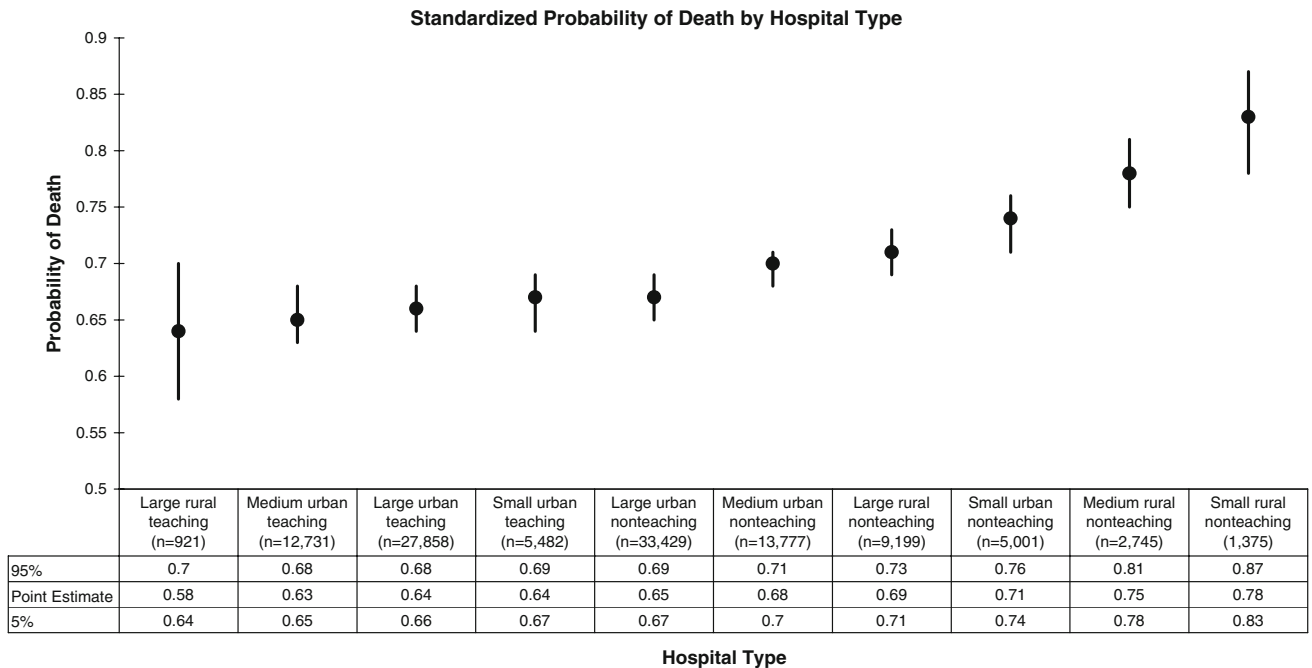


Fig. 3 Standardized probability of death by hospital type. Conditional standardization for male, 65 years old, living in the Northeast, for median income between 51st and 75th percentiles,

for 2002. Inadequate population within small and medium rural teaching hospitals to generate estimate

guidelines aimed at optimizing post-cardiac arrest care [22], there currently exists no epidemiological tool in the United States to monitor survival trends for patients resuscitated from cardiac arrest. The closest approximation is the National Registry of CPR (NRCPR) established in 2000 [23]. NRCPR's design does not allow for the generation of national estimates, and trend data have not yet been reported. The most recent publication from this registry reported that 54% of the 36,902 adults treated for cardiac arrest had initial ROSC [24]. Among the patients with ROSC, in-hospital mortality was 67%, comparable to the 71% that we observed in our analysis. Although it is conceivable that our mortality estimates are erroneously high because we rely on claims data, it is equally plausible that the hospital centers participating in the NRCPR, a voluntary registry comprising over 400 hospitals internationally, may not be representative of the population of US hospitals.

International data support our findings as well. A recent analysis in the UK demonstrated a mortality rate of 71.4% in mechanically ventilated survivors of cardiac arrest who were admitted to the ICU. This analysis included over 24,132 patients from 174 ICUs over a 10-year period [25]. In a recent multicenter study in Canada, the authors found in-hospital mortality to be 64% for patients admitted to the ICU after out of hospital cardiac arrest, and 69% for patients admitted to the ICU after in hospital cardiac arrest [26]. In addition, the authors found substantial variability between hospitals with respect to length of ICU stay after

adjusting for severity and argued that systematic differences in post-arrest care between hospitals were likely contributors. Finally, Niskanen et al. [4] also recently demonstrated a slight reduction of in-hospital mortality after cardiac arrest over time, with most pronounced reductions seen in younger patients and in men.

We demonstrate that hospital factors including teaching status, size, and urban location are associated with mortality differences in patients resuscitated from cardiac arrest. The findings related to hospital type are consistent with international findings related to the effect of hospital type on survival [3, 5, 14, 26]. Treatment at teaching hospitals, urban hospitals, and large hospitals was found to be associated with lower in-hospital mortality. This survival benefit may be attributable to patient-management styles, higher intensity of services, and/or more rapid adoption of new technology and evidence-based practices. The observed differences by hospital type may represent the benefit of a more aggressive approach to the treatment of critically ill patients sustaining cardiac arrest [27], and may help to explain the variability of rates of in-hospital mortality after cardiac arrest that have been reported in the literature.

Our study is a population level cross sectional study using secondary data and as such has limitations. Although we were not able to distinguish between in-hospital and out-of-hospital cardiac arrest, coding guidelines indicate that the ICD-9 code 427.5 is reserved for patients who are successfully resuscitated (experience ROSC) after cardiac

arrest. While there may be variability in the coding of this disease, we have no reason to believe that coding would be systematically different across the hospital types described in this sample or across time. As always, however, there is the potential for imprecision and systematic coding biases. Surveillance data would be improved by distinct diagnostic coding for cardiac arrest and post-cardiac arrest care, or a national health data collection system. We excluded several populations from our analysis. First, we excluded patients with a primary diagnosis of cardiac arrest as these patients are unlikely to represent the population that would benefit from differential inpatient care in the post-arrest state. Our suspicion was validated when these patients, who frequently had only transient ROSC, were found to not have differential survival at large, urban, and teaching hospitals. While they may have benefited from an improved emergency medical response time, or out of hospital defibrillation, they appear to be a different population than those requiring advanced post-cardiac arrest care. In addition, we excluded patients with a secondary diagnosis of cardiac arrest who were discharged alive from the hospital in less than 24 h to avoid including patients undergoing electrophysiology evaluations. Finally, we excluded patients with a secondary diagnosis of cardiac arrest who were transferred from another hospital as we could not tell when their cardiac arrest occurred relative to their transfer.

In our analyses, we were unable to adjust for case mix. Thus, it is possible that our findings are related to differences in patient selection, underlying rhythms, treatment intervals, or pre-hospital systems. We believe it to be unlikely, however, that such systematic bias could exist in a nationally representative sample of hospitals. In fact, large urban teaching hospitals very often manage sicker patients, so we would expect higher mortality rates at these referral facilities rather than the lower rates that we describe. It is therefore possible that our observed effect understates the magnitude of the difference in survival between centers.

Although we determined that differences exist between types of hospitals, we can only hypothesize about why these differences exist. Specifically, we have not considered the many factors believed to exist on the causal pathway of survival after cardiac arrest including clinical factors (initial rhythm, treatment intervals), and

structural factors (nurse staffing ratios, presence of rapid response teams, quality improvement initiatives, etc.). While a potential limitation, we have no reason to believe that these factors would be systematically different based solely on the hospital factors we describe rather than other confounders including payer mix and region of country. Our goal was to identify hospital factors associated with differential survival. Determining the causal factors for this variability represents a rich area for future research as we believe our findings suggest systematic differences not in quality of care but in application of technology and system design to the post-cardiac arrest period [28].

Over the past several decades, a wealth of knowledge has evolved about the recognition [29] and care of the post-cardiac arrest syndrome including formalization of guidelines for research on post-cardiac arrest care [30] and inclusion of evidence-based therapies into Advanced Cardiac Life support [22, 31]. Concurrently, there has been a paradigm shift in the manner that the post-arrest state is managed. The hypothesis that intensive critical care services might improve survival led to advances in the understanding of post-cardiac arrest pathophysiology [32–35], and the benefit of therapeutic hypothermia [15, 16, 20] and other neuroprotective strategies [36]. These scientific discoveries further energized the academic discussion regarding resuscitation of the post-cardiac arrest state, and changes in clinical care are now seen at the bedside. The impact of these advances can only be recognized with epidemiological tools that can accurately monitor outcome trends over time.

This study provides a national analysis of post-cardiac arrest mortality trends in the United States, and suggests a small but significant decrease in post-cardiac arrest mortality between 2000 and 2004. Large, urban, and teaching hospitals demonstrated lower in-hospital mortality relative to small, rural, and non-teaching hospitals. Further research is needed to identify the potential causes of these mortality differences. If better outcomes in large, urban, and teaching hospitals can be causally linked to best practices in post-cardiac arrest care, then mechanisms should be explored to optimize care for all patients resuscitated from cardiac arrest. Options to consider include better translation of best practices to all hospitals [19, 27] and transferring patients to specialized post-cardiac arrest care centers [37, 38].

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