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Variability in case-mix adjusted in-hospital cardiac arrest rates

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Abstract

Background—It is unknown how in-hospital cardiac arrest (IHCA) rates vary across hospitals and predictors of variability.

Objectives—Measure variability in IHCA across hospitals and determine if hospital-level factors predict differences in case-mix adjusted event rates.

Research design—Get with the Guidelines Resuscitation (GWTG-R) (n=433 hospitals) was used to identify IHCA events between 2003-2007. The American Hospital Association survey, Medicare, and US Census were used to obtain detailed information about GWTG-R hospitals.

Subjects—adult patients with IHCA

Measures—Case-mix adjusted predicted IHCA rates were calculated for each hospital and variability across hospitals was compared. A regression model was used to predict case-mix adjusted event rates using hospital measures of volume, nurse-to-bed ratio, percent ICU beds, palliative care services, urban designation, volume of black patients, income, trauma designation, academic designation, cardiac surgery capability and a patient risk score.

Results—We evaluated 103,117 adult IHCAs at 433 US hospitals. The case mix adjusted IHCA event rate was highly variable across hospitals, median 1/1000 bed days (interquartile range: 0.7-1.3 events/1000 bed-days). In a multivariable regression model, case-mix adjusted IHCA event rates were highest in urban hospitals (rate ratio [RR] **1.1**, 95% confidence interval [CI] **1.0-1.3**, p=0.03) and hospitals with higher proportions of black patients (RR 1.2, 95% CI 1.0-1.3, p=0.01) and lower in larger hospitals (RR 0.54, 95% CI 0.45-0.66, p<.0001).

Conclusion—Case-mix adjusted IHCA event rates varied considerably across hospitals. Several hospital factors associated with higher IHCA event rates were consistent with factors often linked with lower hospital quality of care.

Keywords

cardiopulmonary resuscitation; heart arrest; resuscitation

INTRODUCTION

Prevention of cardiac arrest in hospitalized patients represents an important opportunity to improve hospital quality of care (1) as prior studies suggest many of these events are

predictable and avoidable.(2-4) Hospitals have been increasingly focused on reducing IHCA and inpatient mortality.(5, 6) Substantial hospital resources are often devoted to early detection and prevention of respiratory and hemodynamic compromise in hospitalized patients.(6, 7) Accreditation standards mandate that hospitals have a written plan for in-hospital cardiac emergencies(8) and certification in Basic Life Support is required for most hospital-based healthcare providers in the United States (US).

Despite this focus on IHCA prevention, there has not been a national comparison of IHCA rates across hospitals and there are no specific guidelines to direct hospitals in how to best reduce arrest rates. As a result, IHCA event rates likely vary across hospitals. The lack of benchmarking data precludes hospitals from addressing their relative IHCA rates and their individual needs for quality improvement.

Some of the IHCA rate variability could be explained by differences in patient case-mix, as hospitals which provide care for sicker patients are likely to have more arrests. It is unknown however whether there is substantial variation in case-mix adjusted IHCA rates across hospitals, and whether specific hospital level factors (e.g. hospital volume, structural, demographic, and organizational features) predict these rates. This is important to understand, as clinicians and policymakers are increasingly focusing on understanding and identifying indicators of hospital care and quality which impact outcomes and care of hospitalized patients.(9, 10)

To address these issues, our primary aim was to determine how case-mix adjusted IHCA events varied across hospitals participating in the Get With the Guidelines-Resuscitation (GWTG-R), a large ongoing registry of in-hospital resuscitation events in the US. We also sought to determine if hospital level factors explained variability in rates of IHCA.

METHODS

Study database

We used data from the GWTG-R (formerly, National Registry of Cardiopulmonary Resuscitation) to identify in-hospital cardiac arrest events. The GWTG-R is sponsored by the American Heart Association and it is the only prospective database of IHCA in the US. (10) The database was developed primarily for quality improvement, and it is structured to allow hospitals to systematically track treatments and outcomes of patients experiencing IHCA. Data are collected from participating acute care hospitals according to standardized Utstein definitions for in-hospital arrest.(11) Hospitals are encouraged to submit data on all consecutive cardiac arrest events in patients without do-not-resuscitate (DNR) orders. Resuscitation events are included in the database if the event elicits an emergency resuscitation response by hospital personnel and a code record is generated. Cardiopulmonary arrests are specifically defined as events with cessation of cardiac activity determined by the absence of a palpable pulse, apnea and unresponsiveness.

Specially trained nurse or research coordinators at each facility routinely abstract data from medical records and code review sheets regarding: patient demographics, pre-event data, event data, and patient outcomes. The American Heart Association provides rigorous quality control and oversight for all GWTG-R data collection, analysis, reporting and research studies. Additional details regarding the GWTG-R study design are described in detail elsewhere.(10)

Study population

Our study population included patients hospitalized at facilities participating in GWTG-R with documented IHCA. We included in our analysis cardiac arrests in patients 18 years or

older, admitted between January 1, 2003 and December 31, 2007 at hospitals primarily providing care for adult patients. Subsequent arrests in a single patient were included in our analysis if designated as discrete events according to standard GWTG-R definitions. Pediatric hospitals were excluded from the analysis.

Crude event rate

To calculate each hospital's crude event rate, we calculated the number of IHCA divided by bed days. Hospital bed-days were selected as the incidence "denominator" measurement of the population at risk, analogous to person-time. (12, 13) Hospital bed-days were estimated from data reported to the annual American Hospital Association survey and linked with the closest year of data in GWTG-R.

Case-mix adjustment

Hospital acuity—Because IHCA presumably occurs more frequently in populations of severely ill patients, we included several variables in our model to adjust for potential differences in the IHCA event rate that may be due to variation in the acuity level of patients for which a hospital provides care.(14) These variables included trauma hospital designation, cardiac surgery capability, academic designation, and a patient risk score. We specifically assumed that hospitals designated as trauma centers (level 1 and 2), hospitals with cardiac surgery capabilities, and academic hospitals would be more likely to provide care for overall sicker patients, with a consequent higher risk of cardiac arrest.

Trauma designation (level 1, 2 versus other) and academic designation (indicated by membership in the American Association of Medical College's Council of Teaching Hospitals and Health Systems), were obtained from the American Hospital Association annual survey. The capability of a hospital to perform cardiac surgery procedures was determined from Medicare based on billing codes International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] code 361x or Diagnosis Related Group (DRG) codes (106, 107, 109, 547, 548, 549, 550).

Hospital overall patient risk score—We then used inpatient Medicare claims from 2001-2002 (i.e., not during the years of the current study) at all U.S. acute care hospitals to estimate an inpatient mortality logistic regression model. Covariates associated with patient risk included age, gender, race, Elixhauser comorbidity predictors (Appendix A), and DRGs with >500 cases. The c-statistic for this model was 0.85. (15) This model was then applied to claims from all Medicare patients hospitalized at each GWTG-R hospital from 2003-2007 and a mortality risk probability was assigned to each patient. As an estimate of the fraction of patients at each hospital at risk for in-patient death, we then determined the fraction of Medicare patients at each GWTG-R hospital whose risk score exceeded the 75th percentile nationally for risk of inpatient death. We later tested the sensitivity of our main results by varying this risk score cut point from the 66th to 90th percentile nationally. The mean risk score at each hospital was included as a continuous variable in the model.

Organizational factors—Prior investigations have suggested a relationship between hospital volume and resuscitation outcomes (i.e. larger hospitals have better IHCA outcomes).(16) Bed size (number of beds/hospital) was included in our model as a measure of hospital volume. Other organizational factors included categorical measures of percentage of intensive care unit (ICU) beds, and nurse-to-bed ratio in our model using data from the American Hospital Association annual survey.

As one aspect of palliative care services involves helping critically ill patients and their families make decisions about end-of-life care and resuscitation preferences (e.g. DNR

determination), availability of palliative care services (based on data from the American Hospital Association survey) was included in our model as a potentially relevant hospital organizational factor.

Demographic factors

Outcomes from cardiac arrest have been related to socioeconomic factors in prior studies. (17, 18) We used fee-for-service Medicare hospital claims to determine each hospital's inpatient racial composition, reflecting the proportion of claims from black patients (considered a valid measure of race in Medicare data) (19) treated annually for cardiovascular conditions (i.e. diagnosis-related group in major diagnosis category five). We linked zip codes of each hospital's fee-for-service Medicare patients to 2000 U.S. Census data on median household income to approximate the socioeconomic status of the hospital's inpatient population. Urban versus non-urban designation was ascertained from Medicare's Hospital Cost Report Information System. As hospital geographic region (obtained from the US census) could confound hospital level demographic effects we also included region as a covariate in our regression model.

Statistical Analyses

To determine the event rate of IHCA events at GWTG-R hospitals we divided the number of arrest events at each hospital by each hospital's annual bed-days. The numerator was determined from events recorded in GWTG-R and the denominator from the annual reported bed-days per facility. This calculation is reported as events per 1000 bed-days.

Crude event rates were adjusted for case-mix by using a generalized estimating equation (GEE) regression model (20) with the following covariates: bed size, nurse-to-bed ratio, percent ICU beds, palliative care services, urban designation, volume of black patients, median per capita income, trauma designation, academic designation, cardiac surgery capability, and patient risk score. We used GEEs to control for multiple observations of the same hospital across years. Statistical significance across groups was determined using the Kruskal-Wallis test.

To estimate how measures of overall hospital quality and outcomes independently predicted case-mix adjusted IHCA event rates, we estimated a multivariable negative binomial regression model with the following covariates: organizational structure (bed size, nurse-to-bed ratio, percentage of ICU beds, palliative care service availability), demographic characteristics (urban, hospital racial composition, income), and other (trauma designation, academic designation, cardiac surgery capability, patient risk score). We estimated a negative binomial regression model after determining that event rates were excessively dispersed to satisfy the Poisson model assumptions. (21, 22) Results are presented as rate ratios (RR). A p value <.05 was considered statistically significant for all calculations.

Statistical analysis were performed using SAS version 9.1 (SAS Institute Inc, Cary, North Carolina) and Stata version 11, College Station, Texas. This study was approved by the Institutional Review Board at the University of Pennsylvania.

RESULTS

We evaluated a total of 103,117 in-hospital cardiac arrest events at 433 hospitals contributing data to GWTG-R from 2003-2007. In this sample of hospitals, most were medium or large in size (i.e. > 100 beds) (90%), with more than 5% ICU beds (86%). Many were in urban locations (41%) and/or designated as level 1 or 2 trauma centers (42%). Additional characteristics of these hospitals are listed in Table 1.

The case mixed adjusted IHCA event rate was highly variable across hospitals, median 1/1000 bed days (interquartile range [IQR]: 0.7 to 1.3 events/1000). The distribution of these event rates is illustrated in Figure 1. Notably, 8% of hospitals (n=35) had case mix adjusted event rates that were 50% below the median and 3% of hospitals (n=13) had case mix adjusted event rates that were twice the median.

Even when grouping hospitals of similar characteristics, there was significant variation in the mean rate of excess IHCA across hospital size, cardiac surgery capability, and hospital racial composition (Table 2).

Predicting case-mix adjusted IHCA event rates

In a multivariable regression model accounting for measures of hospital volume, structural, demographic, and organizational features (Table 3), we found that hospitals in urban location (RR 1.1, 95% CI 1.0-1.3, $p=0.03$) and hospitals with higher proportions of black patients (RR 1.2, 95% CI 1.0-1.3, $p=0.01$) were both independent predictors of higher IHCA rates. Larger hospitals (RR 0.54, 95% CI 0.45-0.66, $p<.0001$) had lower IHCA rates.

Sensitivity analyses varied the cut point for **the risk score**, without qualitative changes in the results of the model. As the risk score in our model was based on Medicare patients, we also conducted a subsequent analysis and restricted GWTG-R data to patients ≥ 65 years of age. We then estimated the correlation coefficient of **IHCA rates** at each hospital for elderly vs. non-elderly patients. We then re-estimated the negative binomial regression model using the event rate of elderly patients as the dependent variable. The resulting rate ratios for the model did not significantly change except for academic hospitals (RR 0.74, 95% CI 0.63-0.88, $p<.0004$).

DISCUSSION

There is significant and important variation in the rate of cardiac arrest in hospitalized patients that is not explained by case mix. We also identified hospital factors that were independently predictive of IHCA event rates. These findings have meaningful policy implications—as IHCA rates are easily measurable and case-mix adjustment is straightforward, IHCA event rates can potentially be used for tracking hospital performance.

Prior studies have identified variability and potential causes for variability in out-of-hospital cardiac arrest incidence, but less is known about variability and the causes of variability in IHCA incidence.(23, 24) As cardiac arrest in hospitalized patients is both a function of a patients' underlying illness severity and a hospitals' process of care for treating acutely and chronically ill patients, valid comparisons of IHCA event rates must account for risk adjustment of both patient and hospital level factors. This has been evident in prior work of coronary artery bypass graft procedural outcomes illustrating that if risk adjustment is inadequate, outcomes will appear worse in hospitals which provide care for patients with more severe illnesses.(25) We included in our model several measures of patient and hospital case-mix previously studied and readily available in the American Hospital Association survey. Using these variables, we demonstrated that case-mix adjustment of IHCA rates is feasible-and non-GWTG-R hospitals can calculate (Appendix A) their own case-mix adjusted event rate and understand how they compare with other hospitals.

Beyond case-mix, we sought to identify other useful factors that may explain variability in hospital event rates. While the causal pathway for IHCA is complex and multi-factorial, it is important for individual facilities to know how their adjusted IHCA rates compare to other facilities, particularly peer institutions. This knowledge can be a key motivator for quality improvement; Berwick et al refers to this as “move your dot”—an approach for hospitals

looking to compare their organizational performance with in-hospital mortality across hospitals and then improve this rate relative to peer institutions.(26) Clearly, hospitals cannot change their fixed characteristics (size, demographics etc) and it is unlikely that these factors inherently represent the direct mechanisms impacting event rate (i.e. the physical size of the hospital is not protective against IHCA). It is likely however, that these hospital measures provide clues to potentially modifiable factors that impact rates of arrest in hospitalized patients (e.g., large hospitals may be more likely to have rapid response teams).

Other hospital factors predictive of event rate in our model were worrisome and raise equity concerns (e.g., race). The high “excess” IHCA rates at hospitals with large numbers of black patients are troubling, as they provide further evidence that these hospitals may be providing lower quality inpatient care.(27) Prior work shows that black patients with cardiovascular disease are more likely to receive care at hospitals with fewer evidence-based therapies, longer delays in reperfusion treatment, and overall worse risk-adjusted outcomes from cardiac surgery.(28-30) Others have shown that black patients with in-hospital cardiac arrest had longer times to defibrillation than other patients.(18) Clearly a solution to reducing IHCA event rate would not involve altering the demographics of a hospitals’ patient population but rather examining overall process and quality measures in place at hospitals with high rates of arrest in hospitalized patients. Additional work is needed to determine how to best reduce unexpected cardiac emergencies for all hospitalized patients regardless of race.

Our findings related to hospital volume (i.e., smaller hospitals had a higher IHCA event rate and larger hospitals had a lower IHCA event rate) could reflect differences in hospital resources relative to size. Large hospitals may have more resources in place to recognize early indications of clinical deterioration, more advanced technology, and greater overall intensity of services. Although a higher nurse-to-bed ratio was not associated with lower IHCA event rate, there may be other markers of staffing volume (e.g. housestaff coverage, in-house overnight attending coverage, critical care nurse coverage) that we did not measure which may contribute to the observed lower IHCA event rate at large hospitals.

Limitations

Our study was limited in that our estimates of event rate were based on registry data, and while extensive checks were in place to insure a high likelihood of capturing most events at an institution, we cannot verify that all IHCA resuscitations were identified. Our denominator (hospital bed days) may not be recorded accurately at all facilities and may not account for all the potential person-time that could contribute to a hospital’s population at risk of cardiac arrest, including patients seen in clinics, hospital visitors, etc. Nevertheless, bed-days are a commonly measured indicator of hospital size that likely reflects the general dimensions of the population at risk.(12)

We were also limited in our findings and generalizations about event rates at small hospitals (<100 beds) as these are underrepresented in GWTG-R. It is unlikely however that these event rates can be estimated from other existing administrative datasets. Notably, our results also did not change when we excluded small hospitals from the analysis.

It is possible that hospitals participating in GWTG-R may have been motivated to join the registry because they have lower or higher rates of arrest than non-GWTG-R hospitals. This may be important for contextualizing our reported event rates, which therefore might be higher or lower than the general population of US hospitals.

Finally, we identified differences in event rate according to broad hospital categories, but we were unable to fully explain the mechanism that accounts for differences in case-mix

adjusted IHCA. Specifically, there may be differences in end-of-life policies, use of rapid response teams, quality improvement initiatives, or other organizational or demographic factors (e.g. insurance status)(31) that could further explain the variability in event rate across facilities that were not included in our model.(32, 33) In addition, validated quality measures for other cardiovascular diseases (e.g. AMI, heart failure) were not included in our analysis but may correlate with IHCA rates as better surrogates for quality and require further study.

CONCLUSION

There is significant variability in case-mix adjusted IHCA event rates across hospitals and hospital v measures of volume and demographic features explained variation in case-mix adjusted IHCA event rates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

1. Hodgetts TJ, Kenward G, Vlackonikolis I, et al. Incidence, location and reasons for avoidable in-hospital cardiac arrest in a district general hospital. *Resuscitation*. 2002; 54:115–123. [PubMed: 12161290]
2. Schein RM, Hazday N, Pena M, et al. Clinical antecedents to in-hospital cardiopulmonary arrest. *Chest*. 1990; 98:1388–1392. [PubMed: 2245680]
3. Franklin C, Mathew J. Developing strategies to prevent inhospital cardiac arrest: analyzing responses of physicians and nurses in the hours before the event. *Crit Care Med*. 1994; 22:244–247. [PubMed: 8306682]
4. Smith AF, Wood J. Can some in-hospital cardio-respiratory arrests be prevented? A prospective survey. *Resuscitation*. 1998; 37:133–137. [PubMed: 9715771]
5. Berwick DM, Calkins DR, McCannon CJ, et al. The 100,000 lives campaign: setting a goal and a deadline for improving health care quality. *JAMA*. 2006; 295:324–327. [PubMed: 16418469]
6. Flabouris A, Chen J, Hillman K, et al. Timing and interventions of emergency teams during the MERIT study. *Resuscitation*. 2010; 81:25–30. [PubMed: 19913973]
7. Tee A, Calzavacca P, Licari E, et al. Bench-to-bedside review: The MET syndrome--the challenges of researching and adopting medical emergency teams. *Crit Care*. 2008; 12:205. [PubMed: 18254927]
8. Joint Commission on Accreditation of Healthcare Organizations. *Hospital Accreditation Standards*. 2007.
9. Institute of Medicine. *Crossing the quality chasm: a new health system for the 21st century*. National Academy Press; Washington, DC: 2000.

10. Peberdy MA, Kaye W, Ornato JP, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. *Resuscitation*. 2003; 58:297–308. [PubMed: 12969608]
11. Cummins RO, Chamberlain D, Hazinski MF, et al. Recommended guidelines for reviewing, reporting, and conducting research on in-hospital resuscitation: the in-hospital 'Utstein style'. American Heart Association. *Circulation*. 1997; 95:2213–2239. [PubMed: 9133537]
12. Szklo, M.; Nieto, FJ. *Epidemiology: Beyond the Basics*. Aspen Publishers; Gaithersburg: 2000.
13. Sandroni C, Nolan J, Cavallaro F, et al. In-hospital cardiac arrest: incidence, prognosis and possible measures to improve survival. *Intensive Care Med*. 2007; 33:237–245. [PubMed: 17019558]
14. Park RE, Brook RH, Kosecoff J, et al. Explaining variations in hospital death rates. Randomness, severity of illness, quality of care. *JAMA*. 1990; 264:484–490. [PubMed: 2195173]
15. Elixhauser A, Steiner C, Harris DR, et al. Comorbidity measures for use with administrative data. *Med Care*. 1998; 36:8–27. [PubMed: 9431328]
16. Carr BG, Goyal M, Band RA, et al. A national analysis of the relationship between hospital factors and post-cardiac arrest mortality. *Intensive Care Med*. 2009; 35:505–511. [PubMed: 18936907]
17. Chan PS, Nichol G, Krumholz HM, et al. Racial differences in survival after in-hospital cardiac arrest. *JAMA*. 2009; 302:1195–1201. [PubMed: 19755698]
18. Chan PS, Krumholz HM, Nichol G, et al. Delayed time to defibrillation after in-hospital cardiac arrest. *N Engl J Med*. 2008; 358:9–17. [PubMed: 18172170]
19. Arday SL, Arday DR, Monroe S, et al. HCFA's racial and ethnic data: current accuracy and recent improvements. *Health Care Financ Rev*. 2000; 21:107–116. [PubMed: 11481739]
20. Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*. 1986; 42:121–130. [PubMed: 3719049]
21. Hougaard P, Lee ML, Whitmore GA. Analysis of overdispersed count data by mixtures of Poisson variables and Poisson processes. *Biometrics*. 1997; 53:1225–1238. [PubMed: 9423246]
22. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004; 159:702–706. [PubMed: 15033648]
23. Nichol G, Thomas E, Callaway CW, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA*. 2008; 300:1423–1431. [PubMed: 18812533]
24. Rea TD, Cook AJ, Stiell IG, et al. Predicting survival after out-of-hospital cardiac arrest: role of the Utstein data elements. *Ann Emerg Med*. 55:249–257. [PubMed: 19944488]
25. Luft HS, Romano PS. Chance, continuity, and change in hospital mortality rates. Coronary artery bypass graft patients in California hospitals, 1983 to 1989. *JAMA*. 1993; 270:331–337. [PubMed: 8315777]
26. IHI Innovation Series white paper. Institute for Healthcare Improvement; Boston: 2003. Move Your Dot™: Measuring, Evaluating, and Reducing Hospital Mortality Rates (Part 1).
27. Virnig BA, Lurie N, Huang Z, et al. Racial variation in quality of care among Medicare+Choice enrollees. *Health Aff (Millwood)*. 2002; 21:224–230. [PubMed: 12442860]
28. Groeneveld PW, Heidenreich PA, Garber AM. Racial disparity in cardiac procedures and mortality among long-term survivors of cardiac arrest. *Circulation*. 2003; 108:286–291. [PubMed: 12835222]
29. Rothenberg BM, Pearson T, Zwanziger J, et al. Explaining disparities in access to high-quality cardiac surgeons. *Ann Thorac Surg*. 2004; 78:18–24. discussion 24–15. [PubMed: 15223394]
30. Konety SH, Sarrazin MS, Vaughan, Rosenthal GE. Patient and hospital differences underlying racial variation in outcomes after coronary artery bypass graft surgery. *Circulation*. 2005; 111:1210–1216. [PubMed: 15769760]
31. Calvin JE, Roe MT, Chen AY, et al. Insurance coverage and care of patients with non-ST-segment elevation acute coronary syndromes. *Ann Intern Med*. 2006; 145:739–748. [PubMed: 17116918]
32. Ballew KA, Philbrick JT, Caven DE, et al. Predictors of survival following in-hospital cardiopulmonary resuscitation. A moving target. *Arch Intern Med*. 1994; 154:2426–2432. [PubMed: 7979838]

33. Chan PS, Jain R, Nallmothu BK, et al. Rapid Response Teams: A Systematic Review and Meta-analysis. *Arch Intern Med*. 2010; 170:18–26. [PubMed: 20065195]

Figure 1. Distribution of case-mix adjusted in-hospital cardiac arrest event rates

The x-axis represents the case-mix adjusted arrest event rate and the y-axis represents the percentage of hospitals participating in the Get With the Guidelines-Resuscitation registry (n=433 hospitals).

Table 1

Characteristics of GWTG-R hospitals

	GWTG-R N=433	Source
STRUCTURAL		AHAS
Bed size		
Small (6-99)	42 (10%)	
Medium (100-400)	276 (64%)	
Large (>400)	115 (27%)	
Nurse to bed ratio		AHAS
Low (<0.5)	17 (4%)	
Medium (0.5-1)	161 (37%)	
High (>1)	255 (59%)	
Percentage of ICU beds		AHAS
Low (<5%)	61 (14%)	
Medium (5-10%)	235 (56%)	
High (>10%)	127 (30%)	
Palliative care services	199 (47%)	AHAS
DEMOGRAPHIC		
Urban	178 (41%)	HCRIS
Volume black patients		Medicare
Low (<5%)	323 (55%)	
Medium (5-12%)	80 (20%)	
High (>12%)	101 (25%)	
Median per capita income		Census
Low (<\$16000)	33 (8%)	
Medium (\$16-21000)	200 (50%)	
High (>\$21000)	171 (42%)	
OTHER		
Academic	81 (19%)	AHAS
Trauma services (level 1,2)	182 (43%)	AHAS
Cardiac surgery capability	253 (60%)	Medicare

GWTG-R, Get With the Guidelines-Resuscitation, AHAS, American Hospital Association Survey, ICU, Intensive Care Unit, HCRIS, Healthcare Cost Report Information System

Table 2

In-hospital cardiac arrest event rate, unadjusted and adjusted rates

	Unadjusted event rate mean (IQR)	Case-mix adjusted event rate	p
Bed size			0.003*
Small (<100)	1.40 (0.8-1.70)	1.54 (1.32-1.71)	
Medium (100-400)	1.02 (0.61-1.29)	1.0 (0.86-1.47)	
Large (>400)	0.82 (0.51-1.09)	0.84 (0.73-0.94)	
Nurse to bed ratio			0.31
Small (<0.5)	1.13 (0.36-1.74)	1.01 (0.77-1.15)	
Medium (0.5-1)	0.97 (0.58-1.21)	0.96 (0.81-1.01)	
High (>1)	0.99 (0.62-1.27)	1.01 (0.83-1.14)	
Percent ICU beds			0.35
Small (<5%)	1.3	1.23 (1.03-1.3)	
Medium (5-10%)	(0.81-	1.04 (0.85-1.87)	
Large (>10%)	1.74)	0.90 (0.77- 0.99)	
	1.03 (0.63-1.32)		
	0.92 (0.57-1.17)		
Palliative care			0.36
Palliative care services	0.89 (0.56-1.16)	0.90 (0.77-0.99)	
No palliative care services	1.12 (0.65-1.44)	1.1 (.090-1.25)	
Location			0.76
Urban	1.01 (0.59-1.3)	1.0 (0.85-1.11)	
Non-urban	0.98 (0.60-1.25)	0.99 (0.80-1.15)	
Volume black patients			0.04*
Low (<5%)			
Medium (5-12%)	0.92 (0.58-1.16)	0.91 (0.77-0.99)	
High (>12%)	1.02 (0.65-1.25)	1.02 (0.86-1.14)	
	1.19 (0.66-1.62)	1.12 (0.99-1.26)	
Median per capita income			<0.35
Low (<\$16,000)	1.30 (0.81-1.74)	1.23 (1.03-1.30)	
Medium (\$16-21,000)	1.03 (0.63-1.32)	1.04 (0.85-1.88)	
High (>\$21,000)	0.92 (0.57-1.17)	0.90 (0.77-0.99)	
Academic			0.55
Academic designation			
Non-academic designation	0.85 (0.49-1.11)	0.87 (0.74-0.94)	
Trauma			0.39
Trauma (level 1,2)	1.03 (0.63-1.29)	1.03 (0.85-1.18)	
Trauma (not level 1,2)	0.90 (0.54-1.15)	0.91 (0.77-0.98)	
Cardiac surgery capability	1.08 (0.64-1.36)	1.08 (0.89-1.20)	
Cardiac surgery capability			0.01*

	Unadjusted event rate mean (IQR)	Case-mix adjusted event rate	p
Non- cardiac surgery	0.94 (0.61-1.23)	0.95 (0.80-1.07)	
capability	1.07 (0.6-1.32)	1.08 (0.86-1.21)	

*
p<.05,

IQR, interquartile range, ICU, Intensive Care Unit

Table 3

In-hospital cardiac arrest incidence, adjusted rate ratios for hospital factors

	Rate ratio	95% CI	p
STRUCTURAL			
Bed size			
Medium (100-400)	0.63	0.55-0.75	<.001 [*]
Large (>400)	0.54	0.45-0.66	<.001 [*]
Nurse to bed ratio			
Medium (0.5-1)	0.91	0.73-1.1	0.40
High (>1)	0.94	0.75-1.2	0.59
Percent ICU beds			
Medium (5-10%)	0.97	0.86-1.1	0.60
Large (>10%)	1.0	0.88-1.1	0.96
Palliative care services	0.94	0.88-1.0	0.09
DEMOGRAPHY			
Urban	1.1	1.0-1.3	0.03 [†]
Volume black patients			
Medium (5-12%)	1.1	0.94-1.2	0.29
High (>12%)	1.2	1.0-1.3	0.01 [†]
Median per capita income			
Medium (\$16,000-21,000)	0.95	0.81-1.1	0.53
High (>\$21,000)	0.84	0.71-1.0	0.06
OTHER			
Academic	0.95	0.82-1.1	0.53
Trauma	0.94	0.88-1.0	0.12
Cardiac surgery capability	1.1	0.96-1.1	0.3

*
p<.001,†
p<.05