Original Investigation

Resuscitation Practices Associated With Survival After In-Hospital Cardiac Arrest
A Nationwide Survey

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IMPORTANCE Although survival of patients with in-hospital cardiac arrest varies markedly among hospitals, specific resuscitation practices that distinguish sites with higher cardiac arrest survival rates remain unknown.

OBJECTIVE To identify resuscitation practices associated with higher rates of in-hospital cardiac arrest survival.

DESIGN, SETTING, AND PARTICIPANTS Nationwide survey of resuscitation practices at hospitals participating in the Get With the Guidelines–Resuscitation registry and with 20 or more adult in-hospital cardiac arrest cases from January 1, 2012, through December 31, 2013. Data analysis was performed from June 10 to December 22, 2015.

MAIN OUTCOMES AND MEASURES Risk-standardized survival rates for cardiac arrest were calculated at each hospital and were then used to categorize hospitals into quintiles of performance. The association between resuscitation practices and quintiles of survival was evaluated using hierarchical proportional odds logistic regression models.

RESULTS Overall, 150 (78.1%) of 192 eligible hospitals completed the study survey, and 131 facilities with 20 or more adult in-hospital cardiac arrest cases comprised the final study cohort. Risk-standardized survival rates after in-hospital cardiac arrest varied substantially (median, 23.7%; range, 9.2%-37.5%). Several resuscitation practices were associated with survival on bivariate analysis, although only 3 were significant after multivariable adjustment: monitoring for interruptions in chest compressions (adjusted odds ratio [OR] for being in a higher survival quintile category, 2.71; 95% CI, 1.24-5.93; *P* = .01), reviewing cardiac arrest cases monthly (adjusted OR for being in a higher survival quintile category, 8.55; 95% CI, 1.79-40.00) or quarterly (OR, 6.85; 95% CI, 1.49-31.30; *P* = .03), and adequate resuscitation training (adjusted OR, 3.23; 95% CI, 1.21-8.33; *P* = .02).

CONCLUSIONS AND RELEVANCE Using survey information from acute care hospitals participating in a national quality improvement registry, we identified 3 resuscitation strategies associated with higher hospital rates of survival for patients with in-hospital cardiac arrest. These strategies can form the foundation for best practices for resuscitation care at hospitals given the high incidence and variation in survival for in-hospital cardiac arrest.

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In-hospital cardiac arrest occurs in approximately 200 000 patients annually in the United States.[1] Despite a poor prognosis, survival for this condition varies by 3-fold across hospitals from 11% to 35%.[2] Recently, the Institute of Medicine[3] issued a call to action on increasing our understanding of resuscitation practices to prompt renewed efforts for implementation research. Although several strategies, including bystander delivery of cardiopulmonary resuscitation and therapeutic hypothermia, have been linked to better outcomes for out-of-hospital cardiac arrest, resuscitation practices associated with higher survival for in-hospital cardiac arrest remain undefined. Use of feedback devices to optimize cardiopulmonary resuscitation quality[4] and immediate debriefing of team members after resuscitation[5] have been described in single-center studies, but neither is associated with overall survival. Determining which resuscitation practices distinguish hospitals with high survival rates for in-hospital cardiac arrest remains a critical next step to advancing care in these high-risk patients.[6]

The emergence of the Get With the Guidelines (GWTG)-Resuscitation registry has enabled several multicenter investigations of in-hospital cardiac arrest. However, resuscitation practices within hospitals have been infrequently characterized even within the GWTG-Resuscitation registry, and the association of resuscitation practices with in-hospital cardiac arrest survival has not, to our knowledge, been previously examined in any data source. Accordingly, within the GWTG-Resuscitation registry, we performed facility-level surveys to assess resuscitation practices among currently enrolled hospitals. We leveraged recently developed statistical methods to adjust for patient case mix and examined the association of hospitals' resuscitation practices with risk-standardized survival rates for in-hospital cardiac arrest. Our goal was to identify resuscitation practices associated with better performance because these approaches may be potentially shared across facilities to improve overall outcomes.

Key Points

Question What resuscitation practices are used by hospitals with higher survival rates for in-hospital cardiac arrest?

Findings In a cross-sectional study of 131 hospitals participating in a nationwide registry, 3 resuscitation practices were associated with significantly higher survival rates for in-hospital cardiac arrest: monitoring for interruptions in chest compressions, frequent review of cardiac arrest cases, and adequate resuscitation training.

Meaning These strategies can form the foundation for best practices for resuscitation care at hospitals given the high incidence and variation in survival for in-hospital cardiac arrest.

Methods

Study Population

The GWTG-Resuscitation registry is a large, prospective, national quality improvement registry of in-hospital cardiac arrest sponsored by the American Heart Association. Its design has been described in detail previously.[7] In brief, trained quality improvement hospital personnel identify all patients without do-not-resuscitate orders with a cardiac arrest (defined as absence of a palpable central pulse, apnea, and unresponsiveness) who undergo cardiopulmonary resuscitation. Cases are identified by multiple methods, including centralized collection of cardiac arrest flow sheets, reviews of hospital paging system logs, and routine checks of code carts, pharmacy tracer drug records, and hospital billing charges for resuscitation medications.[7] The registry uses standardized Utstein-style definitions for all patient variables and outcomes to facilitate uniform reporting across hospitals.[8,9] In addition, data accuracy is ensured by rigorous certification of hospital staff and use of standardized software with data checks for completeness and accuracy.

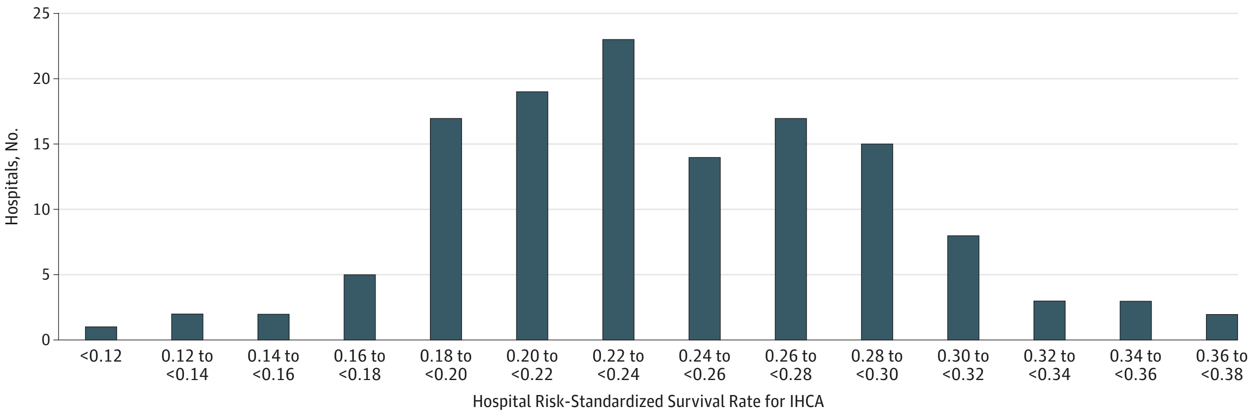
Because in-hospital cardiac arrest survival has improved during the past decade,[10] we restricted our study population to 204 hospitals within the GWTG-Resuscitation registry who were active within the registry during November 2014 (when the survey was initiated) and entered cases from January 1, 2012, through December 31, 2013 (eFigure 1 in the Supplement). Data analysis was performed from June 10 to December 22, 2015. We excluded pediatric hospitals (n = 12) and pediatric cases in hospitals with both pediatric and adult patients. Among the remaining 192 hospitals that were contacted to complete the study survey, 42 did not respond, yielding a completion rate of 78.1%. Hospitals that did not respond had similar characteristics and survival rates for in-hospital cardiac arrest as hospitals that completed the survey (eTable in the Supplement). Finally, among 150 hospitals that completed the study survey, we excluded 19 hospitals with fewer than 20 cardiac arrests (total of 145 cardiac arrest cases) during the 2-year study period. Our final study cohort comprised 17 613 adult patients at 131 hospitals. The institutional review board of the Mid America Heart Institute approved the study protocol. Because the GWTG-Resuscitation registry is a quality improvement registry, informed consent from patients was not required. Patient data are submitted without patient identifiers, and hospitals are deidentified in the data set available for analysis.

Measures and Data Collection

In November 2014, we surveyed resuscitation practices among actively participating hospitals within the GWTG-Resuscitation registry during a 6-month period. Liaisons within each hospital who were connected to the GWTG-Resuscitation registry served as the primary recipient of the survey. The survey was developed based on clinical expertise in our team, outside experts, and the scientific leadership within the GWTG-Resuscitation registry (eFigure 2 in the Supplement). The survey included 45 items on 22 key resuscitation strategies, using multiple-choice questions for each item. Before its implementation period, the survey was field tested by pilot hospital sites for clarity and comprehensiveness.

Resuscitation practices in the survey covered a variety of hospital strategies related to the prevention (eg, use of rapid response teams, standardized risk scores for appropriate hospital unit assignment of admitted patients, and patient-to-nurse ratio), treatment (eg, use of mock codes, intra-arrest

Figure 1. Distribution of Risk-Standardized Survival Rates for In-Hospital Cardiac Arrest (IHCA) Among Study Hospitals



monitoring devices of cardiopulmonary resuscitation quality), and review (eg, immediate debriefing after an acute resuscitation, formal reviews of cardiac arrest cases and quality-of-care measures [survival rates, defibrillation time]) of in-hospital cardiac arrests. Questions on hospital culture included items about administrative leadership, quality improvement, safety, and perceived barriers at one's hospital.

Statistical Analysis

The primary outcome for this study was hospital rates of survival to hospital discharge. For each hospital, we first computed risk-standardized survival rates to hospital discharge for in-hospital cardiac arrest using previously validated methods.[2] Briefly, this published model considered a total of 26 variables to predict survival to discharge after in-hospital cardiac arrest. Using multivariable hierarchical logistic regression, an initial model of 18 predictors was derived with a C statistic of 0.738. Further model reduction yielded a final parsimonious model (C statistic of 0.734) of 9 predictors (age; initial cardiac arrest rhythm; hospital location of arrest; hypotension, sepsis, metastatic or hematologic malignant tumor, and hepatic insufficiency within 24 hours of cardiac arrest; and treatment with mechanical ventilation or need for intravenous vasopressors preceding cardiac arrest). For this study, we reconstructed a hierarchical logistic regression model with our study cohort using these 9 final predictors to forecast survival to hospital discharge. Using the hospital-specific estimates (ie, random intercepts) derived from this hierarchical model, a risk-standardized survival rate for each hospital was determined.[2]

Summary statistics were then used to describe the distribution of hospital rates of risk-standardized survival for in-hospital cardiac arrest in the cohort. To highlight best resuscitation practices at sites with the highest survival rates and to facilitate clinical interpretability of study findings, the hospital sample was divided into quintiles of risk-standardized survival rates for in-hospital cardiac arrest. We then categorized the quintiles into 3 groups to simplify reporting: top quintile, middle 3 quintiles, and bottom quintile. Characteristics of hospitals and patients were then compared across the 3 groups.

For each of the hospital strategies and culture items, we determined the number and percentage of hospitals in each response category. To evaluate the association of specific resuscitation practices and hospital culture with hospital risk-standardized survival rates of in-hospital cardiac arrest, hierarchical logistic regression models were used, which account for clustering of patients within hospitals.[11] For initial bivariate comparisons, we constructed a separate model for each hospital strategy and factor, as well as hospital case volume. We then constructed a multivariable, hierarchical, proportional odds logistic regression model, which included those independent variables that had a bivariate association with hospital risk-standardized survival rates ($P < .10$). A proportional odds logistic regression model was used because it could examine the association between resuscitation practices and a hospital's likelihood of having risk-standardized survival rates in the next-highest quintile category. For instance, a hospital strategy with an odds ratio (OR) of 1.50 would indicate that hospitals using that strategy had 50% greater odds of being in the top hospital survival quintile compared with hospitals in the middle quintiles and of being in the middle quintiles compared with the bottom quintile.

All study analyses were performed with SAS statistical software, version 9.2 (SAS Institute Inc) and R, version 2.10.0.[12] The hierarchical models were fitted with the use of the GLIMMIX macro in SAS statistical software and evaluated at a 2-sided significance level of .05.

Results

Across 131 hospitals, risk-standardized survival rates for in-hospital cardiac arrest varied substantially from 9.2% to 37.5% (median, 23.7%; interquartile range, 20.6%-27.7%) (**Figure 1**). To quantify the extent of variation in survival, the adjusted median OR was 1.47 (95% CI, 1.41-1.57), which suggests that patients with identical covariates had a 47% mean difference in odds of surviving to hospital discharge at 2 different randomly selected hospitals.

The median risk-standardized survival rates for hospitals in the top quintile, middle 3 quintiles, and bottom quintile were 30.9% (interquartile range [IQR], 29.1%-32.8%), 23.6% (IQR, 21.9%-26.3%), and 19.0% (IQR, 15.4%-19.5%), respectively. Hospitals in the top quintile were more likely to be academic hospi-

Table 1. Characteristics of Study Hospitals Stratified by Risk-Standardized Survival Rate Quintiles[a]

Characteristic	Lowest Quintile (n = 26)	Middle 3 Quintiles (n = 78)	Highest Quintile (n = 27)	*P* Value
Hospital Characteristics				
No. of beds, No. (%)				
<200	6 (23.1)	22 (28.2)	13 (48.1)	.09
200-499	14 (53.8)	24 (30.8)	5 (18.5)	
≥500	6 (23.1)	32 (41.0)	9 (33.3)	
Academic status of hospital, No. (%)				
Major teaching	1 (3.8)	22 (28.2)	5 (18.5)	.04
Minor teaching	18 (69.2)	38 (48.7)	13 (48.1)	
Nonteaching	7 (26.9)	18 (23.1)	9 (33.3)	
Rural status, No. (%)				
Rural	1 (6.3)	5 (9.1)	2 (8.7)	.97
Urban	15 (93.8)	50 (90.9)	21 (91.3)	
Missing	10	23	4	
Geographic location, No. (%)				
North Mid-Atlantic	6 (23.1)	15 (19.2)	8 (29.6)	.13
South Mid-Atlantic	7 (26.9)	23 (29.5)	5 (18.5)	
North Central	5 (19.2)	9 (11.5)	7 (25.9)	
South Central	7 (26.9)	11 (14.1)	2 (7.4)	
Mountain Pacific	1 (3.8)	20 (25.6)	5 (18.5)	
Cardiac arrest case volume, median (IQR)	117 (73-186)	84 (40-172)	122 (66-241)	
Demographics, mean (SD)				
Age, y	65.3 (4.9)	66.6 (4.4)	65.2 (3.5)	.23
Male sex, %	58.8 (6.8)	60.0 (9.6)	60.2 (4.3)	.78
Black race, %	33.2 (23.2)	18.1 (17.8)	14.4 (15.2)	<.001
Preexisting conditions, mean (SD), %				
Hypotension	10.4 (9.9)	19.9 (15.3)	28.3 (17.3)	<.001
Sepsis	13.2 (10.8)	15.5 (9.3)	17.8 (9.3)	.21
Metastatic malignant tumor	9.2 (4.6)	11.2 (7.0)	10.9 (7.1)	.43
Hepatic insufficiency	5.1 (4.7)	6.6 (4.4)	7.7 (5.6)	.15
Arrest Characteristics				
Initial cardiac arrest rhythm, mean (SD), %				
Pulseless electrical activity	37.0 (14.7)	29.9 (9.9)	26.5 (8.1)	.001
Asystole	47.5 (11.8)	52.8 (10.1)	51.2 (10.9)	.09
Ventricular fibrillation	9.6 (5.6)	10.0 (4.9)	12.6 (5.2)	.053
Pulseless ventricular tachycardia	6.0 (3.2)	7.3 (4.1)	9.7 (7.3)	.02
Hospital location, mean (SD), %				
ICU	51.7 (11.9)	48.4 (12.1)	44.1 (14.3)	.09
Monitored unit	13.7 (9.0)	13.8 (10.6)	14.1 (9.1)	.99
Nonmonitored unit	14.2 (8.8)	17.4 (11.9)	15.7 (9.5)	.61
Emergency department	12.3 (12.5)	11.6 (10.8)	17.2 (15.5)	.12
Procedural or surgical area	6.1 (3.7)	6.6 (4.4)	7.2 (4.5)	.52
Other	2.0 (2.0)	2.2 (2.8)	1.9 (1.9)	.76
Interventions in place before arrest, mean (SD), %				
Mechanical ventilation	32.2 (15.5)	30.2 (13.6)	35.7 (13.3)	.22
Intravenous vasopressors	20.3 (13.6)	21.0 (10.1)	23.4 (8.2)	.52

Abbreviations: ICU, intensive care unit; IQR, interquartile range.

[a] For age, the mean patient age at each hospital is reported for each quintile group. Otherwise, for other patient variables, rates represent the mean (SD) prevalence rate among hospitals in each quintile group.

tals, but there were no differences in bed number, geographic location, or rural status among the 3 hospital categories (**Table 1**). In general, patient factors were relatively similar between hospitals in the top quintile, middle 3 quintiles, and bottom quintiles. Hospitals in the top quintile had a lower proportion of black patients with cardiac arrest and pulseless electrical activity as the initial cardiac arrest rhythm but were also more likely to have patients with hypotension before cardiac arrest.

Several hospital resuscitation practices had statistically significant bivariate (unadjusted) associations with risk-standardized survival rates for in-hospital cardiac arrest (**Table 2**). Compared with hospitals in the middle quintiles or

Table 2. Unadjusted Associations Between Hospital Strategies and Factors With Risk-Standardized Survival Rates for IHCA

Strategy	Risk-Standardized Survival Rate Groups, No. (%) Lowest Survival Quintile (n = 26)	Middle 3 Survival Quintiles (n = 78)	Highest Survival Quintile (n = 27)	*P* Value for Trend
Strategies to prevent IHCA				
Does your hospital use a risk score for bed-type placement on admission?	5 (19.2)	9 (11.7)	7 (29.2)	.13
Not answered	0	1	3	
Does your hospital discuss code status with all admitted patients?	17 (68.0)	47 (61.0)	17 (65.4)	.95
Not answered	1	1	1	
Does your hospital have a rapid response team?	19 (73.1)	68 (87.2)	23 (85.2)	.51
Does your hospital use root cause analysis to examine IHCAs?	16 (64.0)	48 (62.3)	19 (70.4)	.51
Not answered	1	1	0	
What is your hospital's patient-to-nurse ratio on general medical and surgical floors, patients per nurse?				.33
≤4	4 (15.4)	15 (19.5)	5 (20.0)	
5	11 (42.3)	38 (49.4)	14 (56.0)	
≥6	11 (42.3)	24 (31.2)	6 (24.0)	
Not answered	0	1	2	
Strategies to treat IHCA				
What committee collects and reviews IHCA data?				.66
Dedicated hospital resuscitation committee	16 (64.0)	57 (75.0)	20 (74.1)	
General quality improvement committee	2 (8.0)	8 (10.5)	2 (7.4)	
Other	7 (28.0)	11 (14.5)	5 (18.5)	
Not answered	1	2	0	
How often are IHCAs reviewed?				.19
At least monthly	11 (44.0)	40 (52.6)	15 (55.6)	
Quarterly	9 (36.0)	29 (38.2)	11 (40.7)	
Semiannually or annually	4 (16.0)	4 (5.3)	0	
Not reviewed	1 (4.0)	3 (3.9)	1 (3.7)	
Not answered	1	2	0	
Does your hospital track its survival rate for IHCA?	18 (75.0)	61 (81.3)	21 (77.8)	.94
Not answered	2	3	0	
Does your hospital track its times to defibrillation?	17 (68.0)	55 (72.4)	24 (88.9)	.04
Not answered	1	2		
Does your hospital track interruptions to chest compressions?	6 (24.0)	25 (33.3)	14 (51.9)	.03
Not answered	1	3	0	
Are IHCA events discussed at morbidity and mortality conferences?	8 (32.0)	23 (31.5)	10 (40.0)	.45
Not answered	1	5	2	
Does your hospital conduct mock codes?	24 (96.0)	67 (87.0)	24 (88.9)	.69
Not answered	1	1	0	
Is there a residency training program at your hospital?	15 (57.7)	40 (51.9)	13 (48.1)	.54
Not answered	0	1	0	
How often are code carts checked?				.82
Every shift	11 (42.3)	30 (38.5)	7 (25.9)	
Daily	12 (46.2)	47 (60.3)	20 (74.1)	
Weekly	1 (3.8)	0	0	
Other	2 (7.7)	1 (1.3)	0	
Does your hospital use a dedicated code blue team?	19 (73.1)	59 (75.6)	20 (74.1)	.98
Does your hospital routinely use devices for CPR?				
None used routinely	15 (57.7)	42 (53.8)	12 (44.4)	.31
Yes	0	0	0	
Metronome	0	5 (6.4)	2 (7.4)	.39
CPR device with audio and/or visual feedback	3 (11.5)	12 (15.4)	6 (22.2)	.28
Capnography (continuous end-expiratory carbon dioxide values)	11 (42.3)	25 (32.1)	15 (55.6)	.10
Mechanical CPR device (eg, autopulse, LUCAS)	2 (7.7)	9 (11.5)	2 (7.4)	.76

(continued)

Table 2. Unadjusted Associations Between Hospital Strategies and Factors With Risk-Standardized Survival Rates for IHCA (continued)

Strategy	Risk-Standardized Survival Rate Groups, No. (%) Lowest Survival Quintile (n = 26)	Middle 3 Survival Quintiles (n = 78)	Highest Survival Quintile (n = 27)	*P* Value for Trend
How often is code debriefing performed?				
Always (100% of the time)	0	5 (6.5)	1 (3.7)	.03
Frequently (50%-99% of the time)	6 (24.0)	18 (23.4)	10 (37.0)	
Occasionally (10%-49% of the time)	7 (28.0)	17 (22.1)	10 (37.0)	
Rarely (1%-9% of the time)	10 (40.0)	27 (35.1)	6 (22.2)	
Never (0% of the time)	2 (8.0)	10 (13.0)	0	
Not answered	1	1	0	
Postresuscitation care strategies				
How often is hypothermia begun in comatose patients with ROSC?				
Always (100% of the time)	2 (8.0)	8 (10.5)	4 (15.4)	.31
Frequently (50%-99% of the time)	7 (28.0)	22 (28.9)	7 (26.9)	
Occasionally (10%-49% of the time)	6 (24.0)	18 (23.7)	8 (30.8)	
Rarely (1%-9% of the time)	9 (36.0)	18 (23.7)	5 (19.2)	
Never (0% of the time)	0	2 (2.6)	1 (3.8)	
Therapeutic hypothermia not available at my hospital	1 (4.0)	8 (10.5)	1 (3.8)	
Not answered	1	2	1	
Does your hospital have board-eligible physicians available all the time in ICUs?	13 (50.0)	33 (44.6)	20 (76.9)	.01
Not answered	0	4	1	
What type of ICU model does your hospital use?				
Closed unit	9 (34.6)	18 (25.0)	7 (28.0)	.95
Open unit with mandatory consult for intensive care specialist	7 (26.9)	31 (43.1)	10 (40.0)	
Open unit with multiple physicians or teams	10 (38.5)	23 (31.9)	8 (32.0)	
Not answered	0	6	2	
Hospital culture, leadership, and safety				
Barriers to resuscitation quality				
Lack of direct feedback not a barrier or a weak barrier	14 (53.8)	45 (59.2)	17 (63.0)	.55
Not answered	0	2	0	
Adequate resuscitation training (not a barrier or only mild barrier)	19 (73.1)	62 (81.6)	24 (92.3)	.06
Not answered	0	2	1	
Outdated or insufficient equipment not a barrier or a weak barrier	22 (84.6)	63 (84.0)	25 (96.2)	.13
Not answered	0	3	1	
Lack of support from senior administration not a barrier or a weak barrier	24 (92.3)	65 (86.7)	24 (92.3)	.72
Not answered	0	3	1	
Lack of an appropriate resuscitation champion not a barrier or a weak barrier	17 (65.4)	58 (76.3)	24 (92.3)	.02
Not answered	0	2	1	
Current institution culture not a barrier or a weak barrier	20 (76.9)	60 (80.0)	23 (88.5)	.26
Not answered	0	3	1	

Abbreviations: CPR, cardiopulmonary resuscitation; ICU, intensive care unit; IHCA, in-hospital cardiac arrest; LUCAS, Lund Hospital Cardiac Arrest System; ROSC, return of spontaneous circulation.

the bottom quintile, hospitals in the top quintile were more likely to have cardiac arrests reviewed sooner after their occurrence, track defibrillation times, track interruptions in chest compressions, conduct immediate debriefing after an acute resuscitation, have a dedicated intensive care specialist at all times in their intensive care units, and report adequate resuscitation training. In contrast, hospitals in the bottom survival quintile were much more likely to cite the lack of a resuscitation champion as a moderate or severe barrier at their facility. Notably, a number of other resuscitation strategies had no significant association with in-hospital cardiac arrest survival, including review of cardiac arrests in routine morbidity and mortality conferences, simulation training (mock codes), presence of a rapid response team, use of dedicated cardiac arrest resuscitation teams, allowance for nurses who were not certified in acute cardiac life support to defibrillate patients before arrival of the resuscitation team, frequency of hypothermia treatment, patient-to-nurse ratio, and use of intra-arrest devices for enhancing cardiopulmonary resuscitation quality, such as a metronome, audiovisual feedback, and mechanical devices.

After multivariable adjustment, 3 resuscitation practices were independently associated with hospital rates of risk-standardized survival. Although less than 35% of hospitals rou-

Table 3. Adjusted Associations Between Hospital Factors and Risk-Standardized Survival Rates for In-Hospital Cardiac Arrest

Hospital Resuscitation Strategy or Factor	Adjusted Odds Ratio (95% CI)	*P* Value
Frequency of review of in-hospital cardiac arrest cases		
Less than once quarterly	1 [Reference]	.03
At least once monthly	8.55 (1.79-40.00)	
At least once quarterly	6.85 (1.49-31.30)	
Monitoring for interruptions of chest compressions	2.71 (1.24-5.93)	.01
Adequate resuscitation training at one's hospital (not a barrier or only mild barrier)	3.23 (1.21-8.33)	.02
Monitoring of times to defibrillation	1.89 (0.74-4.83)	.18
Frequency of immediate code debriefing		
Not at all or <10% of all resuscitations	1 [Reference]	.65
10%-49% of all resuscitations	1.19 (0.44-3.23)	
50%-100% of all resuscitations	1.56 (0.61-4.00)	
Presence of intensive care specialist in hospital ICUs at all times	1.84 (0.84-4.00)	.13
Lack of resuscitation champion is a moderate to severe barrier at one's hospital	0.56 (0.21-1.49)	.25

Abbreviation: ICU, intensive care unit.

tinely monitored for interruptions of chest compressions during an acute resuscitation, monitoring of chest compression interruptions was performed in more than half of the hospitals in the top survival quintile. As a result, hospitals that tracked interruptions in chest compressions had a more than 2-fold greater odds of being in a higher survival quintile category than hospitals that did not track cardiopulmonary resuscitation quality (adjusted OR, 2.71; 95% CI, 1.24-5.93; *P* = .01). Moreover, hospitals that reviewed their cardiac arrest cases monthly (adjusted OR, 8.55; 95% CI, 1.79-40.00) or quarterly (adjusted OR, 6.85; 95% CI, 1.49-31.30) had a more than 6-fold odds of being in a higher survival quintile category than hospitals that reviewed their cases less frequently than once quarterly (*P* = .03) (**Table 3**). Hospitals in which staff cited resuscitation training as adequate (ie, not a barrier at all or only a weak barrier) had a greater than 3-fold odds of being in a higher survival quintile category compared with those where it was considered a moderate or severe barrier (OR, 3.23; 95% CI, 1.21-8.33; *P* = .02). Notably, no new hospital practices were identified as significant predictors when we repeated the analyses with hospital risk-standardized survival rates modeled as continuous variables rather than as quintile groups. Finally, the mean (SD) risk-standardized survival rates for hospitals that implemented 1, 2, or all 3 of these strategies (all hospitals implemented at least 1 strategy) were 21.3% (5.5%), 24.3% (5.3%), and 25.8% (4.2%), respectively (**Figure 2**).

Discussion

Using data from acute care hospitals in the United States participating in a national registry, we identified 3 hospital resuscitation practices that were associated with higher hospital rates

Figure 2. Risk-Standardized Survival Rates (RSSRs) for In-Hospital Cardiac Arrest (IHCA) for Hospitals Using 1, 2, or All 3 Resuscitation Practices

of survival for patients with in-hospital cardiac arrest. These strategies included frequent review of cardiac arrest cases, monitoring for interruptions of chest compressions during acute resuscitation, and staff's global assessment of the adequacy of resuscitation training at their site. Other factors that have been suggested as potential innovations in resuscitation care, such as immediate debriefing after cardiopulmonary resuscitation, simulation training (mock codes), dedicated resuscitation teams, use of intraresuscitation monitoring devices, allowing noncritical care nursing staff to defibrillate patients, and patient-to-nurse ratio, were not associated with hospital rates of survival, although the 95% CIs for some of these resuscitation practices were wide. Because risk-standardized survival rates varied substantially, our results provide initial insights into which resuscitation practices may distinguish hospitals with higher rates of survival for in-hospital cardiac arrest.

The emergence of the GWTG-Resuscitation registry in the past 15 years has facilitated numerous studies[13-16] describing the epidemiology and outcomes of in-hospital cardiac arrest. Besides these patient-level studies, other studies[2,17] also have described site-level variation in survival. However, the factors that distinguish top-performing hospitals in cardiac arrest survival from other hospitals were not defined in these studies because information linking resuscitation practices to outcomes has been difficult to obtain. Consequently, identification of best resuscitation practices has been recognized as the critical next step in in-hospital resuscitation research.[6] To date, few studies[18,19] have collected information on hospital resuscitation practices, and none have evaluated the association between these practices and in-hospital cardiac arrest survival. By collecting information on hospital strategies for resuscitation care, we were able to provide insights on hospital practices associated with higher cardiac arrest survival.

Although it makes intuitive sense that more frequent cardiac arrest review could be associated with higher hospital survival for in-hospital cardiac arrest, to our knowledge, this association has not been previously assessed or quantified. In this study, nearly all hospitals in the highest survival quintile reviewed their in-hospital cardiac arrest cases at least once quarterly and many on a monthly basis. In contrast, 1 in 6 hospitals in the lowest survival quintile reviewed their cardiac arrest cases infrequently, although these represented less than

10% of hospitals in the study sample. The process of cardiac arrest case review can identify gaps in resuscitation care and lead to quality improvement efforts to address these gaps. More frequent case review likely increases the efficiency of this feedback cycle and allows for more informative discussions when the cardiac arrest event is relatively recent.

Another strategy we identified—monitoring for interruptions of chest compressions during an acute resuscitation—was used by less than 35% of hospitals but by more than half of the hospitals in the top survival quintile. A study[20] on out-of-hospital cardiac arrest has highlighted the importance of minimizing interruptions in chest compressions during resuscitation care, and changes in advanced cardiac life support training reflect this emphasis. For in-hospital cardiac arrest, a prior study[21] found that use of automated external defibrillators was not beneficial and potentially harmful, presumably because of longer periods of interruptions of chest compressions with deployment of the automated external defibrillator. Further study may be warranted to determine which method of providing feedback for interruptions of chest compressions may be most effective, but our findings suggest that the opportunity to improve may be great because nearly two-thirds of hospitals currently do not monitor this aspect of cardiopulmonary resuscitation quality.

Organizational factors and training have been cited as critical to performance in other conditions, such as door-to-balloon time for ST-segment elevation myocardial infarction.[22,23] In this study, we found that hospital staff citation of adequate resuscitation training was associated with higher cardiac arrest survival. Although we did not evaluate which specific aspects of resuscitation training and preparation optimize the delivery of acute resuscitation and postresuscitation care, our findings highlight that a quick survey of staff perception of adequacy of resuscitation training may be an important routine screen by hospital leaders in identifying gaps in their staff's preparedness and comfort in treating patients with in-hospital cardiac arrest.

Our study should be interpreted in the context of several considerations. Our study may have been underpowered to evaluate some of the hospitals strategies. For instance, in the multivariable model, immediate debriefing after resuscitation was not significantly associated with hospital survival. However, hospitals that conducted immediate debriefing in at least half of their in-hospital cardiac arrests had an adjusted OR of 1.56, and there was a suggestion of a dose-response curve (Table 3). Moreover, although we found that the requirement of a dedicated specialist physician for 24 hours a day/7 days a week in intensive care units was associated with higher hospital rates of survival on bivariate analysis (with 77% of hospitals in the top quintile using this strategy compared with ≤50% in the other 2 hospital categories), this strategy was no longer significantly associated with better survival after multivariable adjustment but did had a large estimate of effect (OR, 1.82; $P = .12$). Further study of several of these resuscitation practices in a larger hospital sample may be warranted to look for their targeted effect on outcomes.

In addition, although 3 hospital strategies were identified, further prospective studies are needed to demonstrate that their dissemination is associated with improved hospital survival, especially in hospitals in the lower quintiles. Development of tools to improve the frequency and content of cardiac arrest case reviews, facilitate monitoring for interruptions of chest compressions, and enhance resuscitation training among hospital staff will be critically important to validate these best practices because we demonstrated associations but not causality, and these practices may be markers of other aspects of resuscitation care. Moreover, because any dissemination strategy to introduce a new behavior involves disruption of existing behaviors, confirmation of the benefits of each of these strategies will be critical.

Our study had other key limitations that affect its interpretation. First, the survey data were reported by a single respondent in collaboration with other staff at the hospital, and the reported policies and practices were not independently confirmed. However, survey respondents were liaisons to the GWTG-Resuscitation registry and were therefore among the most likely individuals to evaluate their institution's resuscitation practices. Moreover, inaccurate responses would be expected to be nondifferential and bias findings toward the null, reinforcing the validity of our positive associations. Second, our study population was limited to hospitals participating in the GWTG-Resuscitation registry, and our findings may not apply to nonparticipating hospitals. Specifically, the prevalence of some resuscitation strategies may be lower in nonparticipating hospitals, and the prevalence of perceived resuscitation barriers may be higher, although the GWTG-Resuscitation registry represents a diverse set of US hospitals with a broad spectrum of hospital risk-standardized survival rates. Third, although the estimates of effect for monthly and quarterly cardiac arrest case reviews were statistically significant, the wide 95% CIs suggest imprecision on the strength of that association. Fourth, some strategies may be important in specific institutions but not necessarily across the full sample because of contextual effects unique to that hospital; therefore, our results should not inhibit innovations that may be effective in particular settings.

Conclusions

Using survey information from acute care hospitals participating in a national quality improvement registry, we identified 3 resuscitation strategies associated with higher hospital rates of survival for patients with in-hospital cardiac arrest. These strategies can form the foundation for best practices for resuscitation care at hospitals, given the high incidence and variation in survival for in-hospital cardiac arrest.

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