

Clinical paper

Duration of hospital participation in Get With the Guidelines-Resuscitation and survival of in-hospital cardiac arrest[☆]

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ABSTRACT

Background: Get With the Guidelines (GWTG-R) is a data registry and quality improvement program for in-hospital cardiac arrest (IHCA). It is unknown if duration of hospital participation in GWTG-R is associated with IHCA outcomes.

Methods: We analyzed adults with IHCA from 362 hospitals participating in GWTG-R between 2000 and 2009. Using logistic regression with generalized estimating equations to account for clustering on hospital, we determined the association between duration of hospital participation in GWTG-R and patient outcomes after IHCA, adjusted for patient and arrest characteristics and secular trend. Using these methods, we also evaluated the association between duration of participation and factors previously correlated with survival after IHCA, including ECG monitored status, after-hours arrest, and time to defibrillation.

Results: Of 104,732 patients with IHCA, 17,646 patients (16.9%) survived to discharge. Duration of hospital participation in GWTG-R was associated with IHCA event survival (per year of participation, odds ratio [OR] 1.02; 95% CI 1.00–1.04; $p = 0.046$) but not survival to discharge (OR 1.02; 95% CI 0.99–1.04; $p = 0.18$). Among factors previously correlated with IHCA survival, duration of participation was associated with time to defibrillation ≤ 2 min (per year of participation, OR 1.06; 95% CI 1.03–1.10; $p < 0.001$), but not ECG monitored status (OR 1.00; 95% CI 0.93–1.06; $p = 0.90$) or survival of after-hours arrest (OR 1.01; 95% CI 0.99–1.03; $p = 0.41$). Among ventricular tachycardia or ventricular fibrillation (VT/VF) arrests, time to defibrillation attenuated the association between duration of hospital participation and outcomes.

Conclusion: Duration of hospital participation in GWTG-R was significantly associated with survival of the IHCA event, but not with survival to discharge. In VT/VF arrests, this association may have been mediated by improvements in time to defibrillation.

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1. Introduction

In-hospital cardiac arrest (IHCA) is a common and high-risk problem with more than 200,000 persons suffering IHCA annually in the United States and fewer than 20% surviving to hospital discharge.^{1,2} As a result, IHCA was targeted as part of a national campaign to reduce in-hospital deaths and significant efforts have

been made to reduce the incidence and mortality of IHCA.^{3,4} One such effort is Get With the Guidelines-Resuscitation (GWTG-R) (formerly known as National Registry of Cardiopulmonary Resuscitation, a data registry and quality improvement program for IHCA supported by the American Heart Association (AHA)).² The GWTG-R allows participating hospitals to systematically track treatments and outcomes of patients experiencing IHCA.

Adherence to guideline-supported processes of care for acute coronary syndromes and heart failure are associated with improved survival.^{5–9} Continued participation in quality improvement initiatives similar to GWTG-R have led to improved processes of care for patients with acute coronary syndromes and stroke.^{5,10–13} Similarly, hospitals recognized for high-performance in quality of care for patients with myocardial infarction or heart failure have lower risk adjusted mortality, explained in part by better processes of care.¹⁴

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Compared with these disease conditions, modifiable factors associated with improved survival of IHCA were poorly defined at the outset of GWTG-R. Early enthusiasm focused on rapid response teams (RRTs) based on reports of decreased incidence and increased survival of IHCA with the implementation of RRTs.^{15–17} Subsequent studies have led to doubts as to the efficacy of RRTs to improve mortality of IHCA.^{18–23} More recently, delays in time to defibrillation of ventricular tachycardia and ventricular fibrillation (VT/VF) arrests, monitored status at the time of arrest, and differential survival of after-hours arrests have been identified as modifiable factors in the survival of cardiac arrest.^{24–26} These modifiable factors in the survival of IHCA are now incorporated into the feedback provided to GWTG-R participating hospitals.²⁷ However, the impact of hospital participation in GWTG-R on survival outcomes for IHCA remains unknown. We sought to determine the association between duration of hospital participation in GWTG-R and patient survival of IHCA, and if changes in survival could be explained by improvements in modifiable factors of IHCA care.

2. Methods

2.1. Study setting and design

We used data from GWTG-R, a prospective multicenter data registry and quality improvement project for IHCA. Participating hospitals voluntarily report data regarding in-hospital resuscitations as identified by an emergency resuscitation response by medical personnel and a resuscitation record. At each facility, trained nurses/research coordinators abstract data from medical records and code review sheets using Utstein definitions for IHCA.²⁸ Data accuracy is facilitated through certification of data entry personnel, case-study methods for newly enrolled hospitals before data submission, and data checks for missing or outlying values. Data reabstraction demonstrated excellent accuracy with a mean error rate of $2.4 \pm 2.7\%$ for all data.² In GWTG-R, cardiac arrest is defined as patient unresponsiveness, apnea, and absence of a central pulse. The resuscitation endpoint is death or return of spontaneous circulation of greater than 20 min duration. The AHA provides quality control and oversight for GWTG-R data collection, analysis, reporting, and research studies. Additional details regarding study design, data collection, and quality oversight of the GWTG-R are described elsewhere.²

2.2. Patient population

We included patients 18 years of age or older with IHCA in an intensive care unit or general ward at a hospital that provided data to GWTG-R for at least 12 months between January 2000 and November 2009 (Fig. 1). Among patients suffering multiple cardiac arrests during the same hospitalization, we identified the first cardiac arrest as the index event and limited our analysis to this event. We excluded patients in emergency departments, operating rooms, procedure areas (i.e. cardiac catheterization, electrophysiology, and angiography suites), and post-procedural areas at the time of their cardiac arrest, due to clinical circumstances in these environments that differ from the general inpatient hospital environment. We excluded patients with unknown survival to discharge or unknown time of arrest, due to the inability to ascertain key time sensitive components in the resuscitation response. Finally, we excluded arrests occurring in hospitals with small arrest volumes (less than 20 arrests per year) to reduce variation related to small sample size at these facilities.

2.3. Duration of GWTG-R participation

Our primary exposure was duration of hospital GWTG-R participation at the time of the patient's IHCA. Duration of participation in GWTG-R was defined as the amount of time between the IHCA event for analysis and the date of the first IHCA reported to GWTG-R for a given hospital. Duration of hospital participation at the time of the IHCA event was categorized by one-year increments.

2.4. Outcomes

Our primary outcome was survival to hospital discharge. Secondary outcomes included survival to 24 h, survival of event (i.e. return of spontaneous circulation for at least 20 min after onset of the arrest), and neurological status as determined by cerebral performance category (CPC) scores, with good CPC scores being equivalent to no major disability. To avoid survivor bias, patients who died prior to discharge were assigned CPC scores equivalent to the worst category (brain death/persistent coma).

2.5. Potential mediators of GWTG-R participation on in-hospital cardiac arrest outcomes

We anticipated participation in GWTG-R would result in improvements in the proportion of patients monitored by telemetry (ECG) at the time of arrest, survival of after-hours arrests (defined as between the hours of 5 PM and 8 AM weekdays or any time on weekends in the present analysis), and shorter time to defibrillation for VT/VF arrests. Additionally, we anticipated any observed improvement in survival of IHCA with GWTG-R participation would be associated with improvements in one or more of these factors.

2.6. Statistical analysis

Baseline patient characteristics and potential mediators of IHCA survival by duration of hospital participation in GWTG-R are reported with descriptive summary statistics. The association between duration of GWTG-R participation and survival to discharge was determined using univariate and multiple logistic regression models adjusted for patient and arrest characteristics, as well as secular trends. We prospectively included variables designated as potential confounders based on prior work and clinical reasoning.^{24–26} These included patient demographics, admitting diagnosis, coexisting medical conditions, treatment interventions in place at the time of arrest, type of hospital bed, first documented pulseless rhythm, and hospital IHCA event rates. We added calendar year to the model to adjust for confounding related to secular trends. Although duration of participation and calendar year were correlated (Pearson correlation coefficient = 0.63), the addition of calendar year did not result in overfitting of the model (variance inflation factor = 2.62).²⁹ Regression models were repeated for the secondary outcomes of survival to 24 h, survival of event, and good CPC score.

The association between duration of GWTG-R participation and potential mediators were assessed by logistic regression, first in unadjusted models for each measure and then in models adjusted for patient characteristics, hospital IHCA event rates, and secular trends. These factors were then included in the multivariable models of duration of GWTG-R participation and IHCA outcomes, to identify associations between GWTG-R participation and survival that were mediated by these factors.

We conducted exploratory analyses in which duration of hospital participation was modeled as an indicator variable to allow for assessment of non-linear associations between duration of hospital participation and IHCA outcomes. Additionally, we conducted

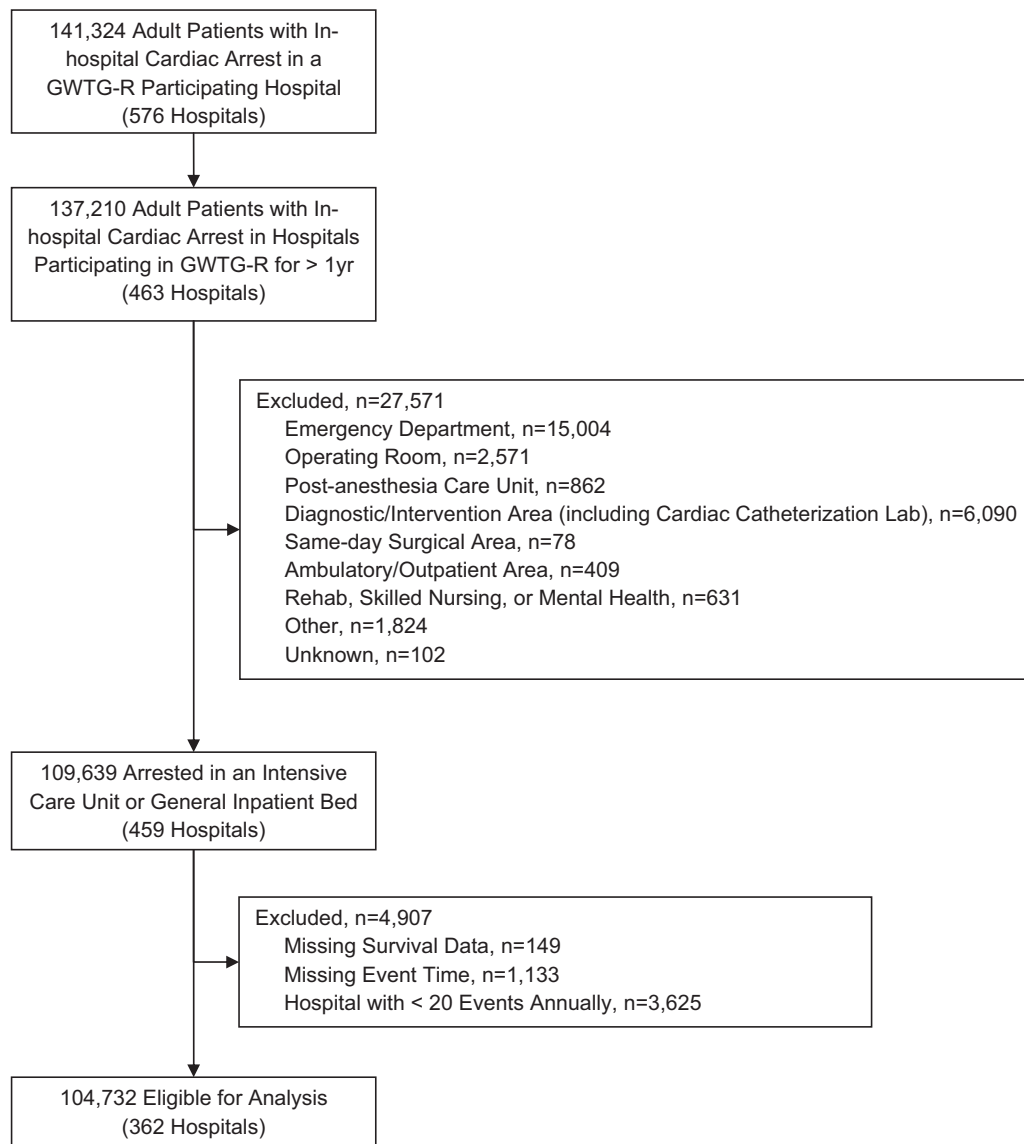


Fig. 1. Get With the Guidelines-Resuscitation Study Cohort.

analyses stratified on hospital duration of participation ≥ 5 years to identify the potential impact of shorter or longer duration of participation in GWTG-R.

All models were constructed as generalized estimating equations with independent correlation matrix and robust variance to account for clustering of patients at the hospital level. All P values are 2 sided, with values of $P < 0.05$ considered statistically significant. All analyses were performed using STATA software version 10.0/MP (StataCorp LP, College Station, TX). The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agreed to the manuscript as written. This study was approved by the Institutional Review Board at the University of Washington.

2.7. Subgroup analyses

Prior studies have suggested that IHCA with VT or VF as the initial rhythm are most amenable to improvements in survival by reducing time to defibrillation. To ensure potential benefits of GWTG-R participation were not obscured by low survival of

non-VT/VF events, we conducted an a priori subgroup analysis restricted to patients with VT or VF as the initial IHCA rhythm.

3. Results

Over a period of nearly 10 years, 141,324 patients suffered IHCA at 576 hospitals participating in GWTG-R. Our analysis included a total of 104,732 IHCA events occurring at 362 hospitals contributing data to GWTG-R for more than one year (Fig. 1). Of 104,732 IHCA events, 20,382 (19.5%) occurred during the first year of hospital participation in GWTG-R, 19,154 (18.3%) in the second year of participation; 16,558 (15.8%) in year three; 13,714 (13.1%) in year four, 11,047 (10.5%) in year five, 8662 (8.3%) in year six, 6718 (6.4%) in year seven, 5083 (4.9%) in year eight, and 2676 (2.6%) in year nine. The smaller number of IHCA occurring in settings of longer duration of GWTG-R participation relates to the staggered entry of participating hospitals such that many hospitals did not participate in GWTG-R for the full period of observation. Patient demographics and clinical characteristics by duration of GWTG-R participation are shown in Table 1. Patients

Table 1
Patient characteristics by years of participation in GWTG-Resuscitation.

Characteristic	Overall (N = 104,732)	Year 1 (N = 20,382)	Year 2 (N = 19,154)	Year 3 (N = 16,558)	Year 4 (N = 13,714)	Year 5 (N = 11,047)	Year 6 (N = 8662)	Year 7 (N = 6718)	Year 8 (N = 5083)	Year 9 (N = 2676)	Year 10 (N = 738)	p Value
Age, mean (SD), year	66.4 (15.7)	67.2 (15.5)	66.8 (15.7)	66.4 (15.6)	66.2 (15.8)	66.2 (15.6)	66.1 (15.7)	65.6 (15.9)	65.1 (15.6)	65.7 (15.6)	65.5 (16.7)	<0.001
Male sex, % ^b	57.8	57.3	57.1	57.9	58.0	57.7	58.1	58.1	59.0	60.0	59.2	0.07
Race/ethnicity, %												
White, non-hispanic	64.6	65.2	64.8	63.9	64.5	64.7	64.6	64.7	64.3	65.0	63.7	
White, Hispanic	3.4	2.4	3.2	3.3	3.2	3.6	4.6	5.1	3.9	2.8	3.5	
Black	21.5	20.8	21.2	21.8	22.1	21.3	20.2	24.2	25.1	25.1	25.2	<0.001
Asian/Native American	1.9	1.7	2.2	1.9	1.6	1.8	2.0	2.3	1.8	1.2	1.1	
Other	1.9	1.4	1.6	2.0	2.5	2.6	2.2	1.7	1.7	2.4	1.0	
Unknown	6.7	8.5	7.1	7.1	6.1	6.0	6.4	5.2	4.2	3.5	5.6	
Illness category, %												
Medical cardiac	32.2	35.5	32.4	32.9	31.7	30.9	30.5	29.7	27.7	32.5	27.0	
Surgical cardiac	7.6	7.7	7.9	8.1	7.3	7.9	7.8	6.6	6.4	5.7	4.7	<0.001
Noncardiac	60.2	56.9	59.8	59.0	61.0	61.2	61.8	63.7	65.9	61.8	68.3	
Prearrest characteristics, % ^a												
CHF during admission	19.6	19.3	19.7	21.0	20.7	20.0	18.7	17.1	17.1	18.1	18.7	<0.001
Prior CHF before admission	22.5	23.8	22.9	23.9	22.4	22.0	21.1	19.3	18.7	21.5	20.9	<0.001
MI during admission	17.1	17.0	17.9	18.4	17.9	17.1	15.4	15.1	14.6	15.3	14.0	<0.001
Prior MI before admission	17.7	18.8	18.7	18.7	17.8	16.5	15.8	15.4	14.3	14.1	16.1	<0.001
Arrhythmia	33.9	30.8	32.5	35.4	38.5	35.8	34.1	32.5	32.1	35.6	39.4	<0.001
Respiratory insufficiency	43.5	40.1	43.0	45.2	46.6	46.0	42.4	42.2	42.8	45.5	45.1	<0.001
Renal insufficiency	35.7	33.7	35.0	36.9	37.7	37.6	35.1	36.2	34.4	36.4	35.0	<0.001
Hepatic insufficiency	8.3	7.3	8.6	8.8	9.4	8.7	7.3	8.7	7.9	7.1	8.8	<0.001
Metabolic/electrolyte abnormality	18.4	16.9	18.8	19.8	21.4	19.0	17.2	15.5	15.2	17.2	17.4	<0.001
Diabetes mellitus	31.6	30.4	30.4	31.8	31.6	33.0	31.8	32.7	33.0	36.7	35.7	<0.001
Acute stroke	4.3	4.6	4.2	4.2	4.3	4.5	4.2	4.5	4.1	3.5	4.3	0.3
Acute nonstroke neurologic event	7.9	7.8	6.6	8.1	9.7	8.6	8.2	6.4	7.4	9.4	9.0	<0.001
Baseline central nervous system deficits	13.3	12.2	12.9	13.8	14.3	14.0	13.6	13.8	12.8	14.5	16.5	<0.001
Pneumonia	15.2	14.2	15.0	15.3	15.5	16.0	15.0	14.9	15.8	17.3	21.3	<0.001
Septicemia	17.3	14.8	17.5	17.4	18.3	19.2	17.5	18.5	18.4	17.0	17.4	<0.001
Hypotension	28.5	25.5	28.4	20.7	32.4	29.2	26.2	26.3	26.7	28.9	34.6	<0.001
Cancer	13.3	13.0	13.7	13.8	13.5	12.9	13.4	13.6	13.1	12.1	9.4	0.02
Major Trauma	3.6	2.9	3.1	3.7	3.5	4.2	4.1	4.4	4.4	4.4	7.3	<0.001
Interventions in place at time of event, %												
Mechanical ventilation ^b	31.8	27.8	29.5	32.5	33.4	32.8	33.1	35.1	37.8	36.3	37.5	<0.001
Vasoactive infusion ^c	29.6	28.6	29.3	30.4	29.3	29.2	29.6	30.5	32.5	31.1	26.7	<0.001
Intraaortic balloon pump ^c	1.6	1.8	1.7	1.6	1.7	1.7	1.5	1.4	1.3	1.2	1.0	0.15
Pulmonary artery catheter ^c	4.3	5.3	4.6	4.7	4.2	3.7	3.8	3.1	2.8	2.0	1.2	<0.001
Hemodialysis ^c	4.1	4.1	3.9	4.1	4.6	4.5	3.7	4.2	3.0	3.3	1.2	<0.001
Hospital arrest location, %												
Intensive care unit	58.3	56.6	57.4	59.2	59.0	58.8	59.1	60.2	58.9	56.6	58.0	
Telemetry or step-down unit	17.2	12.2	14.7	18.4	18.9	18.8	20.3	19.6	21.3	23.6	25.2	<0.001
General medical ward	24.6	31.2	27.9	22.4	22.1	22.4	20.6	20.2	19.8	19.8	16.8	
Arrest characteristics, %												
First pulseless rhythm												
VF/Pulseless VT	19.2	20.8	19.6	20.1	19.4	18.2	18.0	16.5	16.8	16.0	16.7	
PEA	35.5	36.5	36.9	36.0	34.9	34.9	34.8	33.6	33.1	31.5	32.4	
Asystole	39.9	33.7	37.8	38.8	41.7	42.4	43.1	46.5	46.8	49.2	46.3	<0.001
Unknown	5.5	9.0	5.8	5.2	4.1	4.5	4.1	3.4	3.3	3.3	4.6	
Time of day or week of cardiac arrest												
Night, 5PM to 8AM	64.0	64.3	64.4	64.0	63.7	63.5	64.1	63.2	64.4	62.1	64.1	0.35
Weekend	36.3	36.4	36.0	36.0	36.6	36.3	36.9	36.4	36.4	36.0	37.4	0.89

Statistical tests of association were conducted with χ^2 for categorical variables and ANOVA for continuous variables.

^a Missing data 8.6%.

^b Missing data <0.01%.

^c Missing data 4.4%.

Table 2
Arrest outcome by years of participation in GWTG-Resuscitation.

Arrest outcome	Overall (N = 104,732)	Year 1 (N = 20,382)	Year 2 (N = 19,154)	Year 3 (N = 16,558)	Year 4 (N = 13,714)	Year 5 (N = 11,047)	Year 6 (N = 8662)	Year 7 (N = 6718)	Year 8 (N = 5083)	Year 9 (N = 2676)	Year 10 (N = 738)	Unadjusted odds-ratio per 1 year (95% CI)	Adjusted odds-ratio per 1 year (95% CI)
All events													
Survival of event	51.4	47.2	48.6	50.7	52.1	53.9	54.3	56.8	56.6	58.3	58.1	1.06 (1.05–1.07) [#]	1.02 (1.00–1.03) [§]
Survival to 24 h ^a	32.2	30.8	30.6	31.7	32.6	33.6	33.6	34.3	35.3	34.5	36.3	1.03 (1.02–1.04) [#]	1.01 (0.99–1.03)
Survival to discharge	16.9	16.0	15.5	16.8	17.1	17.8	17.7	17.7	19.0	18.4	21.0	1.03 (1.02–1.04) [#]	1.02 (0.99–1.04)
Cerebral performance category ^b													
No major disability	7.3	6.8	6.8	7.4	7.2	7.5	7.3	7.6	8.5	9.3	13.3		
Moderate disability	4.6	4.1	4.3	4.6	4.6	5.2	5.5	5.6	4.9	3.8	4.1	1.04 (1.01–1.06) [§]	1.00 (0.96–1.05)
Severe disability	2.2	2.0	1.7	2.0	2.4	2.5	2.4	2.4	2.5	2.4	1.8		
Coma or vegetative state or death	85.3	87.0	87.3	86.0	85.7	84.8	84.8	84.4	83.2	84.5	80.9		
Arrest outcome	Overall (N = 20,056)	Year 1 (N = 2552)	Year 2 (N = 2307)	Year 3 (N = 2155)	Year 4 (N = 1737)	Year 5 (N = 1352)	Year 6 (N = 1049)	Year 7 (N = 782)	Year 8 (N = 585)	Year 9 (N = 279)	Year 10 (N = 86)	Unadjusted odds-ratio per 1 year (95% CI)	Adjusted odds-ratio per 1 year (95%CI)
VT/VF arrest events													
Survival of event	64.2	60.2	61.5	64.7	65.4	67.4	67.2	70.7	68.4	65.2	69.9	1.06 (1.04–1.08) [#]	1.03 (1.00–1.05) [§]
Survival to 24 h ^c	50.4	47.9	49.1	50.1	51.7	52.9	51.7	55.0	55.6	48.1	56.1	1.03 (1.01–1.05)	1.01 (0.99–1.04)
Survival to discharge	33.8	32.1	32.5	33.0	34.2	35.3	35.6	38.0	36.7	32.2	39.8	1.03 (1.01–1.05)	1.01 (0.98–1.04)
Cerebral performance category ^b													
No major disability	18.2	17.1	17.7	17.6	18.7	18.7	18.7	19.1	20.1	21.2	31.2		
Moderate disability	8.84	7.8	8.9	8.6	8.6	9.9	10.3	11.9	8.9	5.1	4.1	1.03 (1.00–1.07) [§]	1.00 (0.95–1.05)
Severe disability	2.9	2.9	2.4	2.6	3.1	3.2	3.2	3.6	3.3	2.7	2.5		
Coma or vegetative state or death	70.1	72.2	71.1	71.3	69.5	68.2	67.8	65.4	67.0	71.1	61.3		

Statistical tests of trend were assessed using logistic regression with generalized estimating equations to account for clustering by facility. Cerebral performance scores were dichotomized on presence or absence of major disability for tests of trend.

^a Missing data 0.7%.

^b Missing data 2.5%.

^c Missing data 1.2%.

[§] $p < 0.05$.

^{||} $p < 0.01$.

[#] $p < 0.001$.

were older (mean age 70 years), mostly white, and mostly hospitalized for noncardiac illnesses. Common pre-arrest comorbidities included respiratory insufficiency, renal insufficiency, arrhythmia, diabetes mellitus, hypotension, and heart failure. More than half of arrests occurred in the intensive care unit. The first pulseless rhythm was pulseless electrical activity or asystole in nearly 75% of arrests and a majority of arrests occurred at night or on weekends.

Event survival occurred in 53,799 patients (51.4%), survival to 24 h in 33,537 patients (32.2%), and survival to hospital discharge in 17,646 patients (16.9%). Survival outcomes were better for the 20,056 patients with VT/VF arrest with 12,884 patients (64.2%) surviving the event, 9993 patients (50.4%) surviving 24 h, and 6770 patients (33.8%) surviving to hospital discharge. In unadjusted analyses, duration of hospital participation in GWTG-R was associated with an improvement in survival outcomes. After adjustment for patient characteristics, hospital IHCA event rates, and calendar year, the point estimate suggested a weak association that did not achieve statistical significance for outcomes other than event survival (per year of participation, survival of event odds ratio [OR] 1.02; 95% CI 1.00–1.04; $p=0.046$; survival to discharge OR 1.02; 95% CI 0.99–1.04; $p=0.18$). A similar association was observed for duration of GWTG-R participation and outcomes of VT/VF arrests (Table 2). Exploratory analyses allowing for non-linear associations between duration of hospital participation and IHCA outcomes failed to demonstrate meaningful associations due to resultant loss of statistical power. Analyses stratified on duration of participation ≥ 5 years did not demonstrate meaningful differences from the primary analysis (results not shown).

The relationship between duration of hospital participation in GWTG-R was not consistent across factors previously correlated with survival of IHCA. In unadjusted analyses, duration of GWTG-R participation was associated with increased ECG monitoring at the time of arrest and greater survival of after-hours arrests. These associations were not evident after adjusting for patient characteristics, hospital IHCA event rates, and calendar year. Conversely, time to defibrillation ≤ 2 min was not associated with duration of GWTG-R participation in unadjusted analyses. In the adjusted analysis, duration of hospital participation in GWTG-R was associated with improvements in timely defibrillation (per year of participation, time to defibrillation ≤ 2 min OR 1.06; 95% CI 1.03–1.10; $p<0.001$) (Table 3).

The influence of incorporating potential mediators of IHCA survival in our regression analysis is shown in Table 4. Including ECG monitored status or after-hours arrest survival did not influence the association between GWTG-R participation and IHCA outcomes. However, incorporation of time to defibrillation did attenuate the association between duration of participation and outcomes of VT/VF arrests (Table 4).

4. Discussion

In this analysis of over 100,000 IHCA, duration of participation in the GWTG-R program was significantly associated with increased survival of the IHCA event, but not with survival to discharge. In the subgroup of patients with VT/VF arrest, the association between duration of GWTG-R participation and IHCA outcomes appeared to be mediated by improvements in time to defibrillation. The association between duration of GWTG-R participation and survival was not explained by other factors associated with survival of IHCA in prior studies.^{24–26}

Hospital-focused quality improvement programs for cardiovascular diseases, such as acute coronary syndromes and stroke, are associated with improvements in guideline-recommended processes of care.^{5,10–13} Furthermore, providing care in

Table 3
Potential mediators of quality resuscitation by years of participation in GWTG-Resuscitation.

Potential mediator	Overall	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Unadjusted Odds-ratio per 1 year (95% CI)	Adjusted Odds-ratio per 1 year (95% CI)
ECG monitored, % ^a	79.3	74.8	76.4	80.0	80.0	80.5	83.0	84.5	84.8	86.2	86.6	1.10 (1.08–1.12) [†]	1.00 (0.93–1.06)
Survival to discharge of after-hours events	15.7	14.9	14.6	15.8	16.2	16.5	16.6	16.7	17.4	16.8	17.2	1.03 (1.01–1.04) [†]	1.01 (0.99–1.03)
VT/VF event time to defibrillation ≤ 2 min, % ^b	68.2	65.9	68.4	69.9	69.8	69.6	68.8	68.6	66.5	59.6	67.7	1.00 (0.98–1.02)	1.06 (1.03–1.10) [†]

Statistical tests of trend were assessed using logistic regression with generalized estimating equations to account for clustering by facility.

^a Missing data <0.01%.

^b Missing data 12.2%.

[†] $p<0.001$.

Table 4

Survival by duration of hospital participation in GWTG-Resuscitation at the time of in-hospital cardiac arrest.

Odds-ratio per year of GWTG-Resuscitation participation (95% CI)	Unadjusted	Model 1: patient and hospital characteristics and calendar year	Model 1 plus ECG monitored	Model 1 plus after-hours arrest	Model 1 plus time to defibrillation
All events					
Survival of event	1.06 (1.05–1.07) [‡]	1.02 (1.00–1.03) [*]	1.02 (1.00–1.04) [*]	1.02 (1.00–1.04) [*]	N/A
Survival to 24 h	1.03 (1.02–1.04) [‡]	1.01 (0.99–1.03)	1.01 (0.99–1.03)	1.01 (0.99–1.03)	N/A
Survival to discharge	1.03 (1.02–1.04) [‡]	1.02 (0.99–1.04)	1.02 (0.99–1.04)	1.02 (0.99–1.04)	N/A
No major disability	1.04 (1.01–1.06) [*]	1.00 (0.96–1.05)	1.00 (0.96–1.05)	1.00 (0.96–1.05)	N/A
VT/VF arrest events					
Survival of event	1.06 (1.04–1.08) [‡]	1.03 (1.00–1.05) [*]	1.03 (1.00–1.05) [*]	1.03 (1.00–1.05) [*]	1.01 (0.98–1.04)
Survival to 24 h	1.03 (1.01–1.05) [‡]	1.01 (0.99–1.04)	1.01 (0.99–1.04)	1.01 (0.99–1.04)	1.00 (0.97–1.02)
Survival to discharge	1.03 (1.01–1.05) [‡]	1.01 (0.98–1.04)	1.01 (0.98–1.04)	1.01 (0.98–1.04)	1.00 (0.97–1.03)
No major disability	1.03 (1.00–1.07) [*]	1.00 (0.95–1.05)	1.00 (0.95–1.05)	1.00 (0.95–1.05)	0.99 (0.94–1.04)

^{*} $p < 0.05$.[†] $p < 0.01$.[‡] $p < 0.001$.

accordance with practice guidelines is associated with improved patient survival.^{5–9} A notable difference between GWTG-R and quality improvement efforts for other cardiovascular disease states is the relative lack of evidence-based guidelines for processes of care to improve outcomes of IHCA. In fact, only recently were important elements related to survival of in-hospital arrest, such as delays in defibrillation for VT/VF arrests and lower survival of after-hours arrests,^{24–26} identified and incorporated into the monitoring and reporting metrics of the GWTG-R quality improvement efforts. Data on other potentially important processes of care, such as high-quality cardiopulmonary resuscitation (CPR),^{30,31} are challenging to capture and not currently a component of GWTG-R hospital feedback. Additionally, interventions that have demonstrated efficacy in improving outcomes of out-of-hospital cardiac arrest, specifically therapeutic hypothermia,^{32,33} have yet to be assessed in larger controlled interventions or observational studies of IHCA. Limited understanding and challenges in measurement of modifiable processes of care that improve IHCA outcomes may explain the minimal association between duration of GWTG-R participation and IHCA outcomes in the present study. The full potential of the GWTG-R quality improvement effort may be realized through additional insight into processes of care that improve IHCA outcomes and the identification of strategies to implement those processes of care.

In addition to evolving knowledge of IHCA processes of care, other factors may influence the future success of GWTG-R participation to influence IHCA outcomes. The evolution of National Registry of Cardiopulmonary Resuscitation into GWTG-R includes the addition of performance criteria for award recognition beyond simple benchmark comparisons. Award recognition is associated with better care and survival for other cardiovascular conditions.¹⁴ As this transition is recent, the present study lacks data to determine if similar award recognition programs influence IHCA care and survival. Additionally, evidence-based protocols and processes may be insufficient without an organizational culture that supports efforts to improve IHCA care across the hospital. This is suggested by differences in organizational culture observed at high-performing hospitals in the care of patients with acute myocardial infarction.³⁴ Finally, it is possible the association between GWTG-R participation and event survival is not sustained to discharge due to care processes after the IHCA event, such as early withdrawal of care, as has been observed after out-of-hospital cardiac arrest.³⁵ Further

investigation is needed to better understand specific care processes and organizational strategies that are associated with improved survival to discharge following IHCA.

Previous investigations have demonstrated the promise of improving time to defibrillation for IHCA. In work by Chan et al., delayed defibrillation occurred in nearly a third of VT/VF arrests and was associated with a lower likelihood of survival to hospital discharge.²⁴ Several approaches to improving time to defibrillation have been studied. In a single-center study, training non-ICU nurses to perform defibrillation resulted in nearly half of VT/VF arrest patients receiving defibrillation prior to arrival of the code team. This intervention was associated with a statistically non-significant improvement in survival to discharge from 41% to 55%.³⁶ The benefit of automatic external defibrillators (AEDs) to improve time to defibrillation and arrest survival is uncertain. A systematic review suggests AEDs promote safe and timely defibrillation by nurses.³⁷ However, a recent observational study found no correlation between AEDs placed in the hospital and time to defibrillation.³⁸ The modest association between GWTG-R participation and improvements in time to defibrillation suggests strategies to improve time to defibrillation are being implemented successfully. The current study assessed the population-averaged association between duration of hospital participation in GWTG-R and processes of care and outcomes for IHCA. Further investigation is warranted to identify hospitals with greater improvements in time to defibrillation and the strategies that are being implemented at these high-performing hospitals.

Aside from time to defibrillation in VT/VF patients, the association between duration of GWTG-R participation and IHCA event survival was not explained by factors previously correlated with IHCA outcomes.^{24–26} In addition to unmeasured processes of care that may influence IHCA survival, there may be factors that influence the patient population at risk of IHCA and resultant outcomes independent of processes of care. For example, the GWTG-R registry only captures arrest data on patients without do-not-resuscitate orders. Changing emphasis on end-of-life and palliative care services may influence the proportion of hospitalized patients with do not resuscitate orders,^{39–41} particularly among patients with low likelihood of survival.⁴² As a result, the population of patients suffering IHCA captured by GWTG-R may change over time, with outcomes reflecting the patient population at risk as opposed to improvements in processes of care. Although the present analysis

adjusts for secular trends and a wide range of patient factors in an attempt to account for this possibility, attention to factors that influence the population of patients at risk of IHCA will be important to fully understand trends in the outcomes of patients suffering IHCA.

The present study has several strengths, including a large number of patients ($\approx 100,000$) and hospitals (≈ 360) enrolled. The robust data collection and data quality measures of GWTG-R allow for the capture of high quality data with uniform definitions. Additionally, our data analysis accounted for secular trends to allow the independent effect of GWTG-R on outcomes to be estimated despite potential changes in the secular environment.

Our study should be considered in the context of the following limitations. First, hospital participation in GWTG-R is voluntary and may self-select for hospitals invested in quality improvement for care of patients with IHCA: incorporation of nonparticipating hospitals in GWTG-R may not result in similar incremental improvements in IHCA processes of care or patient survival. Second, hospital participation in GWTG-R was often not consistent during the study period as hospitals may leave and reenter as participating GWTG-R sites. Duration of hospital participation was considered continuous because non-participation periods were not readily identified from the data. Lessons learned from GWTG-R participation may extend to improved IHCA outcomes during subsequent non-participation periods, and this assumption would bias our results toward the null. Third, it is possible residual confounding influenced our findings. This could result from inadequate adjustment for measured covariates, unmeasured covariates, or missing data that approached 10% for some patient factors. Fourth, time to defibrillation in GWTG-R is determined from reported times of cardiac arrest and defibrillation. Clocks used for the determination of these times are not synchronized and may lead to misclassification of time to defibrillation. Additionally, the documentation of time within GWTG-R is approximated to the minute level. However, we do not anticipate systematic bias in misclassification or approximation of time to defibrillation.

5. Conclusions

Duration of hospital participation in GWTG-R was significantly associated with survival of the IHCA event, but not with survival to hospital discharge. Of process measures correlated with IHCA arrest survival, duration of GWTG-R participation was associated with time to defibrillation. Improvements in time to defibrillation potentially explain the association between GWTG-R participation and VT/VF event survival.

Conflict of interest statement

The authors have no relevant financial disclosures or conflicts of interest to report.

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References

- Merchant RM, Yang L, Becker LB, et al. Incidence of treated cardiac arrest in hospitalized patients in the United States. *Crit Care Med* 2011;39:2401–6.
- 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.
- Berwick DM, Calkins DR, McCannon CJ, Hackbarth AD. The 100,000 lives campaign: setting a goal and a deadline for improving health care quality. *JAMA* 2006;295:324–7.
- Tee A, Calzavacca P, Licari E, Goldsmith D, Bellomo R. Bench-to-bedside review: the MET syndrome – the challenges of researching and adopting medical emergency teams. *Crit Care* 2008;12:205.
- Schwamm LH, Fonarow GC, Reeves MJ, et al. Get With the Guidelines-Stroke is associated with sustained improvement in care for patients hospitalized with acute stroke or transient ischemic attack. *Circulation* 2009;119:107–15.
- Bradley EH, Herrin J, Elbel B, et al. Hospital quality for acute myocardial infarction: correlation among process measures and relationship with short-term mortality. *JAMA* 2006;296:72–8.
- Fonarow GC, Abraham WT, Albert NM, et al. Association between performance measures and clinical outcomes for patients hospitalized with heart failure. *JAMA* 2007;297:61–70.
- Werner RM, Bradlow ET. Relationship between Medicare's hospital compare performance measures and mortality rates. *JAMA* 2006;296:2694–702.
- Jha AK, Orav EJ, Li Z, Epstein AM. The inverse relationship between mortality rates and performance in the Hospital Quality Alliance measures. *Health Aff (Millwood)* 2007;26:1104–10.
- LaBresh KA, Fonarow GC, Smith Jr SC, et al. Improved treatment of hospitalized coronary artery disease patients with the get with the guidelines program. *Crit Pathw Cardiol* 2007;6:98–105.
- Lewis WR, Peterson ED, Cannon CP, et al. An organized approach to improvement in guideline adherence for acute myocardial infarction: results with the Get With the Guidelines quality improvement program. *Arch Intern Med* 2008;168:1813–9.
- Mehta RH, Montoye CK, Gallogly M, Baker P, Blount A, Faul J, et al. Improving quality of care for acute myocardial infarction: the Guidelines Applied in Practice (GAP) Initiative. *JAMA* 2002;287:1269–76.
- Xian Y, Pan W, Peterson ED, et al. Are quality improvements associated with the Get With the Guidelines-Coronary Artery Disease (GWTG-CAD) program sustained over time? A longitudinal comparison of GWTG-CAD hospitals versus non-GWTG-CAD hospitals. *Am Heart J* 2010;159:207–14.
- Heidenreich PA, Lewis WR, LaBresh KA, Schwamm LH, Fonarow GC. Hospital performance recognition with the Get With the Guidelines Program and mortality for acute myocardial infarction and heart failure. *Am Heart J* 2009;158:546–53.
- Buist MD, Moore GE, Bernard SA, Waxman BP, Anderson JN, Nguyen TV. Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: preliminary study. *BMJ* 2002;324:387–90.
- Bellomo R, Goldsmith D, Uchino S, et al. A prospective before-and-after trial of a medical emergency team. *Med J Aust* 2003;179:283–7.
- DeVita MA, Braithwaite RS, Mahidhara R, Stuart S, Foraida M, Simmons RL. Use of medical emergency team responses to reduce hospital cardiopulmonary arrests. *Qual Saf Health Care* 2004;13:251–4.
- Chan PS, Khalid A, Longmore LS, Berg RA, Kosiborod M, Spertus JA. Hospital-wide code rates and mortality before and after implementation of a rapid response team. *JAMA* 2008;300:2506–13.
- Baxter AD, Cardinal P, Hooper J, Patel R. Medical emergency teams at The Ottawa Hospital: the first two years. *Can J Anaesth* 2008;55:223–31.
- Dacey MJ, Mirza ER, Wilcox V, et al. The effect of a rapid response team on major clinical outcome measures in a community hospital. *Crit Care Med* 2007;35:2076–82.
- Bristow PJ, Hillman KM, Chey T, et al. Rates of in-hospital arrests, deaths and intensive care admissions: the effect of a medical emergency team. *Med J Aust* 2000;173:236–40.
- Hillman K, Chen J, Cretikos M, et al. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet* 2005;365:2091–7.
- Chan PS, Jain R, Nallamothu BK, Berg RA, Sasson C. Rapid response teams: a systematic review and meta-analysis. *Arch Intern Med* 2010;170:18–26.
- Chan PS, Krumholz HM, Nichol G, Nallamothu BK, American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators. Delayed time to defibrillation after in-hospital cardiac arrest. *N Engl J Med* 2008;358:9–17.
- Chan PS, Nichol G, Krumholz HM, Spertus JA, Nallamothu BK, American Heart Association National Registry of Cardiopulmonary Resuscitation (NRCPR) Investigators. Hospital variation in time to defibrillation after in-hospital cardiac arrest. *Arch Intern Med* 2009;169:1265–73.
- Peberdy MA, Ornato JP, Larkin GL, et al. Survival from in-hospital cardiac arrest during nights and weekends. *JAMA* 2008;299:785–92.
- Get With the Guidelines resuscitation: formerly NRCPR (The National Registry of Cardiopulmonary Resuscitation); 2011. Available at: <http://www.heart.org/HEARTORG/HealthcareResearch/GetWithTheGuidelines-Resuscitation/Get-With-The-Guidelines-Resuscitation.UCM.314496.SubHomePage.jsp> [accessed 21.09.11].
- Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates

- for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation* 2004;110:3385–97.
29. Glantz SA, Slinker BK. *Primer of applied regression and analysis of variance*. New York: McGraw-Hill; 1990.
 30. Abella BS, Alvarado JP, Myklebust H, et al. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA* 2005;293:305–10.
 31. Edelson DP, Abella BS, Kramer-Johansen J, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. *Resuscitation* 2006;71:137–45.
 32. Bernard SA, Gray TW, Buist MD, et al. Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. *N Engl J Med* 2002;346:557–63.
 33. Hypothermia after Cardiac Arrest Study Group. Mild therapeutic hypothermia to improve the neurologic outcome after cardiac arrest. *N Engl J Med* 2002;346:549–56.
 34. Curry LA, Spatz E, Cherlin E, et al. What distinguishes top-performing hospitals in acute myocardial infarction mortality rates? A qualitative study. *Ann Intern Med* 2011;154:384–90.
 35. Mccarty K, Nichol N, Chikani V, et al. Early withdrawal of post-arrest care after therapeutic hypothermia in victims of out-of-hospital cardiac arrest. *Circulation* 2010;122:A232 [Abstract].
 36. Coady EM. A strategy for nurse defibrillation in general wards. *Resuscitation* 1999;42:183–6.
 37. Kenward G, Castle N, Hodgetts TJ. Should ward nurses be using automatic external defibrillators as first responders to improve the outcome from cardiac arrest? A systematic review of the primary research. *Resuscitation* 2002;52:31–7.
 38. Chan PS, Krumholz HM, Spertus JA, et al. Automated external defibrillators and survival after in-hospital cardiac arrest. *JAMA* 2010;304:2129–36.
 39. Head BA, Lajoie S, Augustine-Smith L, et al. Palliative care case management: increasing access to community-based palliative care for Medicaid recipients. *Prof Case Manag* 2010;15:206–17.
 40. O'Mahony S, McHenry J, Blank AE, et al. Preliminary report of the integration of a palliative care team into an intensive care unit. *Palliat Med* 2010;24:154–65.
 41. Bakitas M, Lyons KD, Hegel MT, et al. Effects of a palliative care intervention on clinical outcomes in patients with advanced cancer: the Project ENABLE II randomized controlled trial. *JAMA* 2009;302:741–9.
 42. Reisfield GM, Wallace SK, Munsell MF, Webb FJ, Alvarez ER, Wilson GR. Survival in cancer patients undergoing in-hospital cardiopulmonary resuscitation: a meta-analysis. *Resuscitation* 2006;71:152–60.