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Duration of resuscitation efforts for in-hospital cardiac arrest by predicted outcomes: Insights from Get With The Guidelines – Resuscitation☆

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ABSTRACT

Background: The duration of resuscitation efforts has implications for patient survival of in-hospital cardiac arrest (IHCA). It is unknown if patients with better predicted survival of IHCA receive longer attempts at resuscitation.
Methods: In a multicenter observational cohort of 40,563 adult non-survivors of resuscitation efforts for IHCA between 2000 and 2012, we determined the pre-arrest predicted probability of survival to discharge with good neurologic status, categorized into very low (<1%), low (1–3%), average (>3%–15%), and above average (>15%). We then determined the association between predicted arrest survival probability and the duration of resuscitation efforts.
Results: The median duration of resuscitation efforts among all non-survivors was 19 min (interquartile range 13–28 min). Overall, the median duration of resuscitation efforts was longer in non-survivors with a higher predicted probability of survival with good neurologic status (median of 16, 17, 20, and 23 min among the groups predicted to have very low, low, average, and above probabilities, respectively; $P < 0.001$). However, the duration of resuscitation was often discordant with predicted survival, including longer than median duration of resuscitation efforts in 40.4% of patients with very low predicted survival and shorter than median duration of resuscitation efforts in 31.9% of patients with above average predicted survival.
Conclusions: The duration of resuscitation efforts in patients with IHCA was generally consistent with their predicted survival. However, nearly a third of patients with above average predicted outcomes received shorter than average (less than 19 min) duration of resuscitation efforts.

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Introduction

Despite 200,000 in-hospital cardiac arrests occurring in the United States each year,[1] the duration of resuscitation efforts that should be provided before deeming a resuscitation attempt unsuccessful remains unknown.[2] The lack of empiric data on this fundamental question of resuscitation care has resulted in dramatic variation in clinical practice, with some hospitals on average attempting resuscitation for victims of in-hospital cardiac arrest

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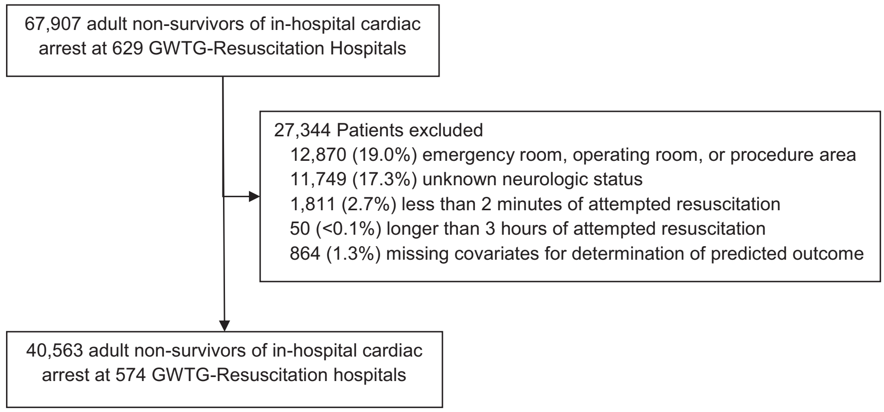

Fig. 1. Study cohort.

for twice as long as other hospitals.[3] This variation in practice is not inconsequential, as evidenced by higher survival rates after in-hospital cardiac arrest at hospitals where resuscitation efforts are generally longer.[3]

Prior studies suggest nearly 90% of patients who achieve return of spontaneous circulation after an in-hospital cardiac arrest will do so within 30 min of the onset of their arrest.[3] While this suggests a possible minimum duration of resuscitation efforts, the decision to terminate attempts is difficult for providers and should be balanced against an individual patient's probability of survival.[4–6] For example, among patients with very low predicted survival (e.g. frail elderly patients, advanced malignancy), prolonged resuscitation efforts may reflect care with low utility.[7] Conversely, among patients with a better than average predicted survival of in-hospital arrest, early termination of resuscitation efforts may suggest an inadequate resuscitation attempt.

Using data from a large, national, registry of in-hospital cardiac arrest in the United States, we sought to describe the duration of resuscitation efforts among non-survivors of in-hospital cardiac arrest. We then sought to determine if resuscitation efforts were longer among patients with above average predicted outcomes as determined from pre-arrest characteristics. Finally, we examined the proportion of arrest patients whose duration of resuscitation was discordant with their predicted outcome (e.g. shorter than average resuscitation attempt despite above average predicted survival, and vice versa) and characteristics associated with risk-treatment mismatch in the duration of resuscitation efforts. Understanding resuscitation duration as it relates to predicted survival may inform opportunities to improve resuscitation care and patient outcomes after in-hospital cardiac arrest.

Methods

Study setting and design

The American Heart Association's (AHA) Get with the Guidelines®—Resuscitation (GWTG-R) is a large, U.S. national, prospective multicenter data registry and quality improvement program for in-hospital cardiac arrest and served as the data source for this analysis. Details regarding the registry have been described elsewhere.[8] Briefly, participating hospitals voluntarily report data on patients without do-not-resuscitate orders and with a confirmed cardiac arrest (defined by the lack of a palpable central pulse, apnea, and unresponsiveness) who received cardiopulmonary resuscitation (CPR). Case-finding approaches used to ensure complete capture of in-hospital cardiac arrest cases include review of cardiac-arrest flow sheets and the hospital paging-system logs, routine checks of code carts (carts stocked with emergency medications and equipment) and pharmacy tracer drug records, and hospital billing charges for use of resuscitation medications.[9] At each facility, data from code review sheets and medical records is abstracted by trained staff using Utstein definitions for in-hospital cardiac arrest.[10] Data accuracy is facilitated through certification of data entry personnel, data checks for missing or outlying observations, and case-study methods for newly enrolled hospitals prior to data submission. The AHA provides quality control and oversight for GWTG-R data collection, analysis, reporting and research studies. Outcome, A Quintiles Company, is the data collection coordination center for the American Heart Association/American Stroke Association Get With The Guidelines® programs.

Patient population

We identified 67,907 adult non-survivors with in-hospital cardiac arrest at 629 hospitals between 2000 and 2012. We excluded 12,870 (19.0%) patients whose cardiac arrest occurred in emergency departments, operating rooms, areas of post-operative, rehabilitative, and procedural care (e.g., cardiac catheterization, electrophysiology, and angiography suites), or unknown location as these settings reflect distinct circumstances (Fig. 1). Additionally we excluded 11,749 (17.3%) patients with unknown neurologic status on admission and 864 (1.3%) patients with missing values for covariates necessary for the determination of predicted survival (see below). Finally, we excluded 1861 (2.7%) patients with incomplete data on resuscitation duration, or who received less than 2 min or longer than 3 h of resuscitation to avoid "partial" resuscitations or multiple in-hospital cardiac arrests that re-occurred in the same patient over a short period of time. The final analytic cohort included 40,563 patients from 574 hospitals.

Predicted probability of survival to discharge with good neurologic status

Using a model previously validated in GWTG-R and based on 13 pre-arrest characteristics (age, illness category, pre-existing conditions [major trauma, acute stroke, metastatic or hematologic cancer, septicemia, hepatic insufficiency, hypotension or hypoperfusion, renal insufficiency or dialysis, respiratory insufficiency, pneumonia], residence prior to admission, and neurologic status), we determined the pre-arrest predicted probability of survival to discharge with good neurologic status (defined as neurologically intact or with minimal deficits based on a Cerebral Performance

Category score of 1).[6] From this model, a predicted survival score ("GO-FAR Score") was calculated (range −15 to 53) and these scores were then categorized into very low (<1%), low (1–3%), average (>3%–15%), and above average (>15%) predicted survival with good neurological status based on prior application of this model to the GWTG-R population.[6] In a prior study, the model demonstrated good calibration with a Hosmer–Lemeshow $\chi2$ statistic of 11.39 (P = 0.18) and a C statistic of 0.78 when applied to a validation set of GWTG-R patients.

Duration of resuscitation efforts

The outcome of interest was the duration of resuscitation efforts. This was defined in our cohort of non-survivors of IHCA as the time interval between the onset of arrest and the time when cardiopulmonary resuscitation was terminated. Both reported times were recorded in minutes in GWTG-R and determined from cardiac arrest documentation in the patient's medical records.

Statistical analysis

Characteristics of patients were compared by categories of predicted survival probability using Mann-Whitney Wilcoxon non-parametric tests for continuous variables and chi-square tests for categorical variables. We then described the duration of resuscitation efforts in the patient cohort (median, IQR, and range) and determined the association between predicted arrest survival probability and the duration of resuscitation efforts. We first evaluated this association using continuous data for both the predicted arrest survival probability (numeric GO-FAR score) and the duration of resuscitation efforts (minutes) with local polynomial regression. We then evaluated the distribution of categories of resuscitation duration derived from the entire cohort (<25th percentile, 25th to <50th percentile, 50th to <75th percentile, and ≥75th percentile) across categories of GO-FAR predicted survival (very low [<1%], low [1–3%], average [>3%–15%], and above average [>15%]) to explore discordance in the duration of resuscitation relative to predicted outcomes.

To identify patient, arrest, and hospital characteristics associated with mismatches in the duration of resuscitation efforts in relation to predicted outcomes, we compared characteristics by duration of resuscitation efforts (i.e. longer or shorter than the median 19 min) in stratified analyses of patients with very low or above average GO-FAR predicted survival categories. We then performed stratified hierarchical logistic regression to identify patient, arrest, and hospital characteristics independently associated with a risk-treatment mismatch in the duration of resuscitation efforts. Candidate predictor variables included demographics, prearrest characteristics, interventions in place before arrest, arrest characteristics, and hospital characteristics (see Table 1 and 2 for details). In this analysis, we excluded hospitals with fewer than 10 observations (269 hospitals and 3799 patients [9.4%]) to facilitate stable estimates from the hierarchical model.

Statistical analyses were performed with SAS/STAT software, version 9.4 of the SAS System for Windows and all two-sided statistical tests were evaluated at a significance level of 0.05. This study was approved by the Colorado Multiple Institutional Review Board.

Results

In our cohort of 40,563 patients suffering in-hospital cardiac arrest, the predicted survival to discharge with good neurologic status was very low in 4801 (11.8%) patients, low in 8889 (21.9%), average in 19,910 (49.1%) patients, and above average in 6963 (17.2%) patients (Table 1). Patients with lower predicted survival outcomes were older and more likely to have cancer, pneumonia, acute stroke, hypotension, or insufficiency of respiratory, renal, or hepatic function. Patients with lower predicted survival outcomes were also more likely to have been admitted from a skilled nursing facility and present with pulseless electrical activity.

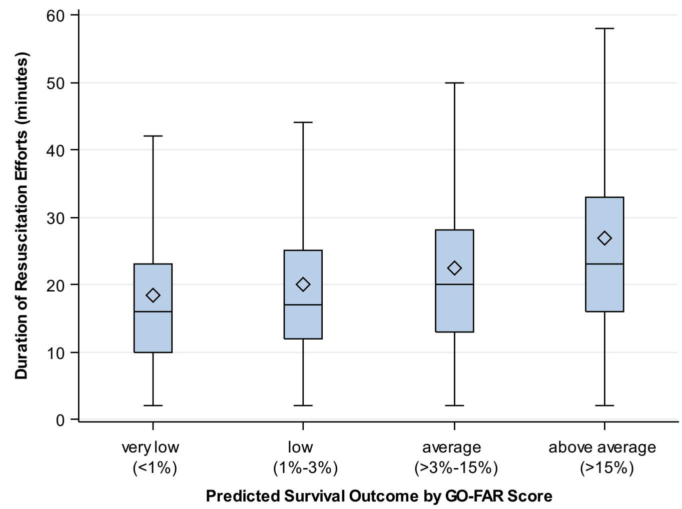

Fig. 2. Duration of attempted resuscitation by predicted probability of survival to discharge with good neurologic outcome for each box-and-whisker plot, the center line represents the median duration of resuscitation, the box represents the 25th–75th percentile, the whiskers represent the 1st–99th percentile, and the diamond represents the mean duration of resuscitation efforts for each category of predicted survival outcome.

The median duration of attempted resuscitation was 19 min (interquartile range [IQR] 13 min–28 min, range 2 min–180 min). The pre-arrest predicted probability of arrest survival was associated with a longer duration in resuscitation efforts (Fig. 2). By categories of pre-arrest predicted survival, the median duration of attempted resuscitation was 16 min in patients with very low predicted survival (IQR 10–23), 17 min in patients with low predicted survival (IQR 12–25), 20 min in average predicted survival (IQR 13–28), and 23 min in patients with above average predicted survival (IQR 16–33) (P for linear trend test <0.001).

The evaluation of resuscitation duration within categories of pre-arrest predicted survival outcomes demonstrated 40.4% of patients with very low predicted survival received more than the median duration of 19 min of attempted resuscitation and 15.6% received attempted resuscitation for a duration that exceeded the 75th percentile for the overall cohort, equivalent to more than 28 min of attempted resuscitation. Among patients with above average predicted survival, 31.9% received less than the median duration of 19 min of attempted resuscitation. Furthermore, 14.1% of patients with above average predicted survival received less than the 25th percentile duration of 13 min of attempted resuscitation (Fig. 3).

Patient, arrest, and hospital characteristics by duration of resuscitation efforts for patients with very low or above average GO-FAR predicted survival categories are provided in the Online Supplement. Results of our stratified hierarchical analysis to identify patient, arrest, and hospital characteristics associated with mismatches in the duration of resuscitation efforts in are shown in Table 2. Among patients with very low predicted survival, characteristics independently associated with longer than average resuscitation efforts included surgical cardiac diagnosis, intravenous vasopressor at the time of arrest, and initial arrest rhythm. Among patients with above average predicted survival, characteristics independently associated with shorter than aver-

Table 1
Patient characteristics by predicted probability of survival to discharge with good neurologic outcome.

	Overall N = 40,563	Predicted probability of survival to discharge with good neurologic status: Very low (<1%) N = 4801 (11.8)	Low (1%–3%) N = 8889 (21.9)	Average (>3%–15%) N = 19,910 (49.1)	Above Average (>15%) N = 6,963 (17.2)	P value
Demographics, no. (%)						
Age, y						<0.001
<70	20,024 (49.3)	1376 (28.7)	3840 (43.2)	10,198 (51.2)	4610 (66.2)	
70-74	4770 (11.8)	405 (8.4)	945 (10.6)	2402 (12.1)	1018 (14.6)	
75-79	5509 (13.6)	722 (15.0)	1200 (13.5)	2735 (13.7)	852 (12.2)	
80-84	5147 (12.7)	801 (16.7)	1338 (15.1)	2525 (12.7)	483 (7.0)	
>84	5113 (12.6)	1497 (31.2)	1566 (17.6)	2050 (10.3)	0 (0)	
Men	24,607 (60.7)	2723 (56.7)	5229 (58.8)	12,245 (61.5)	4410 (63.3)	<0.001
White	28,113 (69.6)	3053 (63.9)	5903 (66.7)	14,102 (71.2)	5055 (72.9)	<0.001
Prearrest conditions, no. (%)						
Illness category						<0.001
Medical noncardiac diagnosis	20,118 (49.6)	3984 (83.0)	5689 (64.0)	9565 (48.1)	880 (12.6)	
Medical cardiac diagnosis	12,402 (30.6)	478 (10.0)	1927 (21.7)	6362 (31.0)	3635 (52.2)	
Surgical noncardiac	4877 (12.0)	199 (4.1)	717 (8.1)	2463 (12.4)	1498 (21.5)	
Surgical cardiac	2190 (5.4)	65 (1.4)	221 (2.5)	1030 (5.2)	874 (12.6)	
Trauma	922 (2.3)	75 (1.6)	331 (3.7)	474 (2.4)	42 (0.6)	
Heart failure this admission	7653 (18.9)	878 (18.3)	1545 (17.4)	3717 (18.7)	1513 (21.2)	<0.001
Previous heart failure	9040 (22.3)	1133 (23.6)	1979 (22.3)	4374 (21.9)	1554 (22.3)	0.11
Myocardial infarction this admission	6227 (15.4)	435 (9.1)	1034 (11.6)	3079 (15.5)	1679 (24.1)	<0.001
Previous myocardial infarction	6888 (17.0)	705 (14.7)	1314 (14.8)	3405 (17.1)	1464 (21.0)	<0.001
Arrhythmia	12,728 (31.4)	1806 (37.6)	2931 (33.0)	6017 (30.2)	1974 (28.4)	<0.001
Hypotension or hypoperfusion	11,945 (29.5)	2622 (54.6)	3283 (36.9)	5208 (26.2)	832 (12.0)	<0.001
Respiratory insufficiency	17,568 (43.3)	3233 (67.3)	4776 (53.7)	8223 (41.3)	1336 (19.2)	<0.001
Renal insufficiency or dialysis	14,336 (35.3)	2824 (58.8)	3784 (42.6)	6610 (33.2)	1118 (16.1)	<0.001
Hepatic insufficiency	3423 (8.4)	997 (20.8)	970 (10.9)	1381 (6.9)	75 (1.1)	<0.001
Acute stroke	1721 (4.2)	570 (11.9)	594 (6.7)	516 (2.6)	41 (0.6)	<0.001
Pneumonia	6390 (15.8)	1452 (30.2)	1727 (19.4)	2829 (14.2)	382 (5.5)	<0.001
Septicemia	7357 (18.1)	2605 (54.3)	1987 (22.4)	2668 (13.4)	97 (1.4)	<0.001
Major trauma	1412 (3.5)	259 (5.4)	498 (5.6)	655 (3.3)	0 (0.0)	<0.001
Metastatic or hematologic cancer	6232 (15.4)	1298 (27.1)	1743 (19.6)	2957 (14.9)	234 (3.4)	<0.001
Metabolic or electrolyte abnormality	7544 (18.6)	1561 (32.5)	2049 (23.1)	3335 (16.8)	599 (8.6)	<0.001
Diabetes mellitus	12,264 (30.2)	1518 (31.6)	2643 (30.0)	5951 (30.0)	2151 (30.9)	0.047
Neurologically intact or with minimal deficits at admission	20,919 (51.6)	86 (1.8)	910 (10.2)	1296 (65.1)	6963 (100)	<0.001
Admit from skilled nursing facility	3691 (9.1)	1698 (35.4)	1272 (14.3)	704 (3.5)	17 (0.2)	<0.001
Interventions in place before arrest, no. (%)						
Mechanical ventilation	12,566 (31.0)	1991 (41.5)	3163 (35.6)	5982 (30.1)	1430 (20.5)	<0.001
Intravenous vasopressor medication	13,558 (33.4)	1778 (37.0)	2941 (33.1)	6541 (32.9)	2298 (33.0)	<0.001
Dialysis	1613 (4.0)	315 (6.6)	405 (4.6)	776 (3.9)	117 (1.7)	<0.001
Intra-aortic balloon pump	485 (1.2)	9 (0.2)	57 (0.6)	240 (1.2)	179 (2.6)	<0.001
Pulmonary-artery catheter	1415 (3.5)	127 (2.7)	280 (3.2)	714 (3.6)	294 (4.2)	<0.001
Characteristics of the cardiac arrest						
Initial cardiac-arrest rhythm, no (%)						<0.001
Asystole	17,099 (42.2)	2318 (48.3)	4025 (45.4)	8319 (41.9)	2437 (35.1)	
Pulseless electrical activity	16,640 (41.1)	18,313 (38.2)	3463 (39.0)	8213 (41.3)	3133 (45.1)	
Ventricular fibrillation	3638 (9.0)	337 (7.0)	733 (8.3)	1774 (9.0)	794 (11.4)	
Pulseless ventricular tachycardia	1856 (4.6)	187 (3.9)	394 (4.4)	913 (4.6)	362 (5.2)	
Time to first defibrillation attempt, min; med (IQR)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	0.25
Hospital location of arrest, no. (%)						<0.001
Intensive care unit	9199 (22.7)	1258 (26.2)	2007 (22.6)	4585 (23.0)	1349 (19.4)	
Monitored unit	6633 (16.4)	535 (11.1)	1239 (14.0)	3267 (16.4)	1592 (22.9)	
Nonmonitored unit	9831 (24.2)	1177 (24.5)	2275 (25.6)	4922 (24.7)	1457 (20.9)	
Hospital-wide response activated, no. (%)	35,232 (86.9)	4150 (86.4)	7685 (86.5)	17,330 (87.0)	6067 (87.1)	0.38
Assessed with AED, no. (%)	5680 (14.0)	689 (14.4)	1226 (13.8)	2741 (13.8)	1024 (14.7)	0.12
Time of arrest, no. (%)						
Arrest at night (11 pm–7 am)	15,471 (38.3)	1808 (37.8)	3377 (38.1)	7668 (38.6)	2618 (37.8)	0.47
Arrest on weekend	11,623 (28.7)	1351 (28.1)	2590 (29.1)	5654 (28.4)	2028 (29.1)	0.38

Table 2
Association between patient, arrest, and hospital characteristics and mismatched duration of resuscitation efforts for predicted risk of survival outcomes.

	Very low predicted survival with good neurologic status		Above average predicted survival with good neurologic status	
	OR (95% CI) for above average resuscitation duration	P value	OR (95% CI) for below average resuscitation duration	P value
Demographics				
Age (10 years older)	0.99 (0.99, 0.996)	<0.001	1.02 (1.01, 1.02)	<0.001
Men	1.09 (0.94, 1.26)	0.25	1.05 (0.92, 1.19)	0.46
Race				
White	Reference		Reference	
Black	1.18 (0.98, 1.41)	0.07	0.88 (0.74, 1.04)	0.13
Asian/Pacific Islander	0.89 (0.50, 1.59)	0.70	0.63 (0.31, 1.30)	0.21
American Indian/Eskimo	0.98 (0.20, 4.83)	0.98	1.09 (0.44, 2.66)	0.86
Prearrest conditions, no. (%)				
Illness category				
Medical noncardiac diagnosis	Reference		Reference	
Medical cardiac diagnosis	0.85 (0.64, 1.13)	0.27	0.73 (0.59, 0.92)	0.007
Surgical noncardiac	0.86 (0.59, 1.26)	0.45	0.79 (0.63, 0.99)	0.04
Surgical cardiac	2.05 (1.06, 3.97)	0.03	0.41 (0.31, 0.54)	<0.001
Trauma	0.86 (0.43, 1.74)	0.68	NA	
Heart failure this admission	0.88 (0.71,1.09)	0.26	1.00 (0.85, 1.18)	0.99
Previous heart failure	0.98 (0.81, 1.19)	0.87	1.20 (1.02, 1.41)	0.03
Myocardial infarction this admission	1.18 (0.91, 1.54)	0.22	0.86 (0.73, 1.01)	0.07
Previous myocardial infarction	1.19 (0.96, 1.48)	0.10	0.91 (0.78, 1.06)	0.23
Arrhythmia	1.10 (0.94, 1.29)	0.24	0.89 (0.77, 1.03)	0.11
Hypotension or hypoperfusion	0.94 (0.78, 1.12)	0.46	1.68 (1.38, 2.06)	<0.001
Respiratory insufficiency	0.97 (0.81, 1.17)	0.77	0.97 (0.81, 1.15)	0.69
Renal insufficiency or dialysis	1.16 (0.98, 1.37)	0.08	1.19 (0.99, 1.42)	0.06
Hepatic insufficiency	0.99 (0.80, 1.21)	0.90	1.18 (0.65, 2.15)	0.58
Acute stroke	1.18 (0.91, 1.53)	0.21	1.11 (0.51, 2.40)	0.80
Pneumonia	1.06 (0.91, 1.25)	0.45	1.07 (0.82, 1.40)	0.60
Septicemia	0.93 (0.79, 1.11)	0.44	1.53 (0.94, 2.50)	0.09
Major trauma	1.23 (0.82, 1.84)	0.31	NA	
Metastatic or hematologic cancer	1.04 (0.86, 1.25)	0.70	1.59 (1.15, 2.21)	0.005
Metabolic or electrolyte abnormality	1.01 (0.85, 1.19)	0.95	1.13 (0.91, 1.41	0.25
Diabetes mellitus	1.03 (0.88, 1.21)	0.71	0.86 (0.75, 0.98)	0.03
Neurologically intact or with minimal deficits at admission	0.91 (0.51, 1.63)	0.75	NA	
Admit from skilled nursing facility	0.88 (0.74, 1.05)	0.16	2.30 (0.80, 6.63)	0.12
Interventions in place before arrest, no. (%)				
Mechanical ventilation	0.53 (0.44, 0.65)	<0.001	2.05 (1.73, 2.42)	<0.001
Intravenous vasopressor medication	1.86 (1.56, 2.22)	<0.001	0.50 (0.43, 0.58)	<0.001
Dialysis	0.91 (0.68, 1.22)	0.51	1.16 (0.73, 1.84)	0.53
Intra-aortic balloon pump	4.82 (0.85, 27.28)	0.08	1.93 (1.31, 2.84)	<0.001
Pulmonary-artery catheter	0.88 (0.54, 1.45)	0.62	0.71 (0.51, 0.98)	0.04
Characteristics of the cardiac arrest				
Initial cardiac-arrest rhythm, no (%)				
Asystole	Reference		Reference	
Pulseless electrical activity	1.47 (1.25, 1.73)	<0.001	0.71 (0.62, 0.81)	<0.001
Ventricular fibrillation	1.58 (1.18, 2.12)	0.002	0.73 (0.59, 0.90)	0.004
Pulseless ventricular tachycardia	2.37 (1.61, 3.48)	<0.001	0.78 (0.59, 1.03)	0.08
Hospital location of arrest, no. (%)				
Intensive care unit	0.65 (0.49, 0.87)	0.004	1.50 (1.22, 1.85)	<0.001
Monitored unit	Reference		Reference	
Nonmonitored unit	0.75 (0.57, 0.97)	0.03	1.30 (1.06, 1.59)	0.02
Hospital-wide response activated, no. (%)	0.76 (0.59, 0.97)	0.03	1.15 (0.94, 1.40)	0.18
Assessed with AED, no. (%)	0.88 (0.77, 1.01)	0.07	1.09 (0.98, 1.21)	0.10
Time of arrest, no. (%)				
Arrest at night (11 p.m.–7 a.m.)	1.15 (0.96, 1.30)	0.15	0.93 (0.83, 1.06)	0.32
Arrest on weekend	1.20 (1.02, 1.41)	0.02	1.01 (0.88, 1.15)	0.94
Hospital characteristics				
Hospital region				
Mountain/Pacific	Reference		Reference	
North/Mid Atlantic	2.23 (1.43, 3.50)	<0.001	1.04 (0.77, 1.40)	0.81
South Atlantic	1.10 (0.73, 1.67)	0.64	1.18 (0.92, 1.52)	0.20
North Central	1.34 (0.87, 2.05)	0.18	0.97 (0.74, 1.28)	0.85
South Central	1.33 (0.80, 2.20)	0.27	0.88 (0.65, 1.18)	0.39
Teaching status				
Non-teaching	Reference		Reference	
Major teaching	1.44 (1.03, 2.01)	0.03	0.64 (0.51, 0.79)	<0.001
Minor teaching	1.25 (0.95, 1.66)	0.12	1.01 (0.83, 1.23)	0.93
Owner type				
Private	Reference		Reference	
Nonprofit	1.08 (0.78,1.50)	0.65	0.95 (0.77, 1.18)	0.66
Government	1.89 (1.08, 3.30)	0.02	1.06 (0.75, 1.50)	0.74
Military	2.29 (0.83, 6.34)	0.11	1.32 (0.72, 2.41)	0.36

age resuscitation efforts included older age, prior heart failure, hypotension/hypoperfusion, mechanical ventilation or intra-aortic balloon pump at the time of arrest, and arrest location.

Discussion

In a large, U.S. registry of in-hospital cardiac arrest, we sought to describe the association between pre-arrest predicted outcomes and the duration of resuscitation efforts. Among 40,000 patients

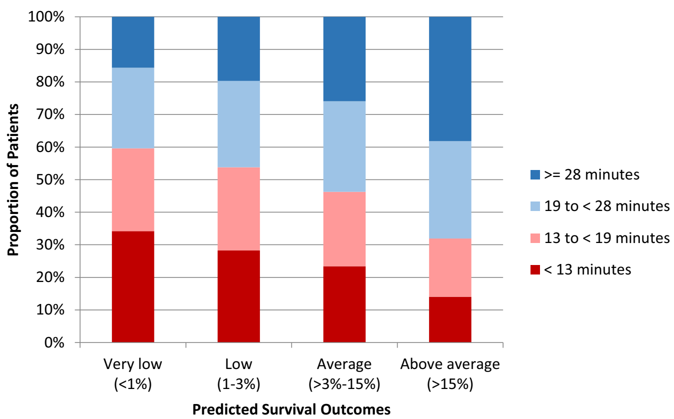

Fig. 3. Resuscitation duration by predicted probability of survival outcome categories of resuscitation duration were constructed from the quartiles of duration of resuscitation efforts (i.e. <25th percentile, 25th to <50th percentile, 50th to <75th percentile, and ≥75th percentile) for the entire cohort.

suffering in-hospital cardiac arrest, those patients with an above average predicted survival with good neurologic status received resuscitation efforts that were on average 7 min longer for patients with a very low (<1%) predicted outcome. However, nearly 1 in 3 patients with above average predicted probabilities for favorable neurologic survival received shorter than average (i.e. less than 19 min) attempted resuscitation. This may reflect missed opportunities to provide an adequate duration of resuscitation efforts to optimize patient outcomes following in-hospital cardiac arrest.

Prior observational studies have provided insights on patient outcomes as a function of resuscitation duration. Among 31,198 adult patients who experienced return of spontaneous circulation after in-hospital cardiac arrest, 87.6% achieved this outcome within 30 min of the onset of resuscitation efforts and resuscitation efforts lasting more than 30 min prior to ROSC were not associated with a less favorable neurologic status at discharge.[3] These findings contrast with another smaller study of in-hospital cardiac arrest that suggested survival to hospital discharge is low among adult patients who remain pulseless after 10 min of resuscitation.[11] In comparison, studies of patients with out-of-hospital cardiac arrest suggest that 90% of survivors with good neurologic outcome achieved return of spontaneous circulation within 20 min of the onset of resuscitation.[12,13] In the present study, less than half of patients received at least 20 min of resuscitation prior to termination of efforts and less than 1 in 4 received at least 30 min of resuscitation. Furthermore, among patients with above average predicted survival outcomes, nearly 1 in 3 received less than 20 min of resuscitation efforts.

Failure to provide adequate duration of resuscitation may contribute to the low survival of in-hospital cardiac arrest. Prior studies have demonstrated better patient survival at hospitals with longer average attempts at resuscitation of in-hospital cardiac arrest.[3] Although this finding may represent aspects of resuscitation quality beyond the duration of resuscitation efforts, it underscores to the potential for longer resuscitation efforts to improve patient outcomes. This is particularly pertinent for the nearly 20% of patients with above average predicted survival by pre-arrest characteristics.

Although longer resuscitation efforts have the potential to improve survival for some patients, it is important to recognize that extended resuscitation efforts may not be aligned with best care or patient preferences, particularly in settings of very low predicted survival outcomes.[2,7] Additionally, resuscitation care demands the devotion of significant healthcare resources to an individual patient, including providers who may be responsible for the care of a number of patients simultaneously. It is important to ensure these resources are appropriately targeted to optimize the health outcomes of all patients under the care of these providers.

The analysis of patients with mismatch in the duration of attempted resuscitation relative to predicted outcomes suggested some arrest characteristics (i.e. presenting rhythm of ventricular tachycardia or ventricular fibrillation) were associated with longer resuscitation attempts among patient with very low pre-arrest predicted survival, while other pre-arrest characteristics (i.e. age, prior heart failure, hypotension/hypoperfusion, malignancy, mechanical ventilation or intra-aortic balloon pump at the time of arrest, and arrest location) were associated with shorter resuscitation attempts among patients with above average pre-arrest predicted survival. The findings of longer attempted resuscitation among patients with ventricular tachycardia or ventricular fibrillation is reassuring given better survival among patients with these presenting rhythms. Similarly, shorter attempted resuscitation among patients with malignancy may reflect concordance with longer term patient prognosis. However, these findings may also suggest an overemphasis on certain patient factors in decisions to terminate resuscitation efforts. Additionally, these findings highlight the potential need to consider intra-arrest data (i.e. presenting rhythm) when informing decisions on duration of resuscitation efforts.

In an era of increasing emphasis on “big data” and predictive analytics, tools could be deployed in routine care to calculate and include pre-arrest predicted survival of in-hospital cardiac arrest as part of the patient’s medical record. As the variables necessary for this calculation are determined from pre-arrest characteristics, this predictive tool could be applied as part of daily patient assessments. This would ensure that the results of the model would be available prior to the outset of an in-hospital cardiac arrest event, rather than requiring calculation during the arrest itself. Ideally, the results of this model could be further refined to provide a range of potential outcomes for differing arrest presentations (i.e. asystole, PEA, or VT/VF) allowing rapid incorporation of intra-arrest data at the time of an event. This approach could inform providers on resuscitation treatment decisions, including the duration of resuscitation efforts, thereby minimizing overemphasis of individual pre-arrest characteristics on treatment decisions and reducing risk-treatment mismatch in resuscitation efforts.

Strengths of the current study include the use of national, multicenter data from a well-established in-hospital cardiac arrest registry. Furthermore, our emphasis on non-survivors of cardiac arrest is a strength as the duration of resuscitation efforts in this setting reflects choices in clinical care delivery, rather than patient recovery from cardiac arrest. However, our study results should also be considered in light of the following limitations. The time interval between onset of cardiac arrest and termination of resuscitation efforts is captured in minutes in GWTG-R and limits the ability to evaluate this time interval using smaller units of time. Furthermore, we cannot exclude misclassification of time intervals related to challenges of exact documentation of event times during in-hospital arrest care; although, this would be expected to bias the association between predicted survival and resuscitation duration toward the null in the absence of differential misclassification. Second, we cannot exclude the possibility of unmeasured confounding in this observational study. Third, although the predictive model used in our analysis was previously developed and validated in GWTG-R and provides reassurance in the application of this model for the present study, the generalizability of the GO-FAR score to other patients with in-hospital cardiac arrest is unknown. Similarly, our analysis was restricted to in-hospital arrests occurring on general wards, telemetry units, and intensive care units at hospitals participating in GWTG-R with volumes adequate to support stable modeling estimates. Our findings may not be generalizable to arrests in emergency departments, operating rooms, areas of post-operative, rehabilitative, procedural care, or smaller hospitals and hospitals that do not participate in GWTG-R. Fourth, the duration of resuscitation efforts may be influenced by evidence of delayed recognition of cardiac arrest, as well as unmeasurable factors (e.g., resuscitation performance and quality, family presence during the resuscitation, or family directives).

In conclusion, in a national study of more than 40,000 non-survivors of in-hospital cardiac arrest, longer attempts at resuscitation were provided to patients with better predicted survival outcomes. However, nearly a third of patients with above average predicted survival received resuscitation efforts that were less than 19 min in duration. Ensuring patients receive an adequate attempt at resuscitation efforts may be one approach to improving survival of cardiac arrest.

Conflict of interest statement

The authors report no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work, and no other relevant relationships with industry or other disclosures.

Disclosures

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