Defibrillation time intervals and outcomes of cardiac arrest in hospital: retrospective cohort study from Get With The Guidelines-Resuscitation registry

Steven M Bradley,^{1,2,3} Wenhui Liu,^{1,4} Paul S Chan,⁵ Brahmajee K Nallamothu,⁶ Gary K Grunwald,^{1,4} Alyssa Self,² Comilla Sasson,⁷ Paul D Varosy,^{1,2,3} Monique L Anderson,⁸ Preston M Schneider,^{2,3} P Michael Ho^{1,2,3} for the American Heart Association's Get With The Guidelines-Resuscitation Investigators

¹VA Eastern Colorado Health Care System, Denver, CO, USA

²University of Colorado School of Medicine, Aurora, CO, USA

³Colorado Cardiovascular Outcomes Research Consortium, Denver, CO, USA

⁴University of Colorado School of Public Health, Aurora, CO, USA

⁵Saint Luke's Mid America Heart Institute and University of Missouri-Kansas City, MO, USA

⁶University of Michigan Medical School, Ann Arbor, MI, USA

⁷American Heart Association, Dallas, TX, USA

⁸Duke Clinical Research Institute, Durham, NC, USA

Correspondence to: S M Bradley, VA Eastern Colorado Health Care System, Department of Veterans Affairs, 1055 Clermont Street (111B), Denver, CO 80220-3808, USA. Steven.Bradley@va.gov

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ABSTRACT OBJECTIVE

To describe temporal trends in the time interval between first and second attempts at defibrillation and the association between this time interval and outcomes in patients with persistent ventricular tachycardia or ventricular fibrillation (VT/VF) arrest in hospital.

DESIGN

Retrospective cohort study.

SETTING

172 hospitals in the United States participating in the Get With The Guidelines-Resuscitation registry, 2004-12.

PARTICIPANTS

Adults who received a second defibrillation attempt for persistent VT/VF arrest within three minutes of a first attempt.

INTERVENTIONS

Second defibrillation attempts categorized as early (time interval of up to and including one minute between first and second defibrillation attempts) or deferred (time interval of more than one minute between first and second defibrillation attempts).

MAIN OUTCOME MEASURE

Survival to hospital discharge.

RESULTS

Among 2733 patients with persistent VT/VF after the first defibrillation attempt, 1121 (41%) received a deferred second attempt. Deferred second defibrillation for persistent VT/VF increased from 26% in 2004 to 57% in 2012 ($P<0.001$ for trend). Compared with early second defibrillation, unadjusted patient outcomes were significantly worse with deferred second defibrillation (57.4% v 62.5% for return of

spontaneous circulation, 38.4% v 43.6% for survival to 24 hours, and 24.7% v 30.8% for survival to hospital discharge; $P<0.01$ for all comparisons). After risk adjustment, deferred second defibrillation was not associated with survival to hospital discharge (propensity weighting adjusted risk ratio 0.89, 95% confidence interval 0.78 to 1.01; $P=0.08$; hierarchical regression adjusted 0.92, 0.83 to 1.02; $P=0.1$).

CONCLUSIONS

Since 2004, the use of deferred second defibrillation for persistent VT/VF in hospital has doubled. Deferred second defibrillation was not associated with improved survival.

Introduction

Defibrillation is critical in the resuscitation of patients with cardiac arrest due to ventricular tachycardia or ventricular fibrillation (VT/VF). Resuscitation guidelines have previously called for up to three successive or "stacked" shocks with minimal time delays between defibrillation attempts.¹ The use of stacked shocks, however, can result in prolonged interruptions of chest compressions that can contribute to poor patient outcomes.²⁻⁵ As a result, in 2005 resuscitation guidelines were revised to support single shock protocols with two minutes of chest compressions between defibrillation attempts to minimize interruptions in compressions.⁶⁻⁸

Several studies of cardiac arrest outside hospital support the current resuscitation guidelines for the management of VT/VF with single shock protocols.⁹⁻¹¹ A prior randomized trial comparing a stacked versus single shock protocol in the management of cardiac arrest outside hospital, however, found no difference in patients' outcomes.¹² Furthermore, the characteristics of VT/VF arrest in hospital differ from outside hospital in ways that can influence the relative importance of rhythm termination versus chest compressions. Compared with patients with VT/VF outside hospital, patients with VT/VF in hospital are often monitored or witnessed at the time of arrest, resulting in rapid recognition of arrest and shorter times to initiation of chest compressions and first attempt at defibrillation.¹³ As a result, they are treated in the earlier phases of cardiac arrest, when an emphasis on rhythm termination with shorter intervals between defibrillation attempts might improve outcomes.¹⁴ More frequent defibrillation attempts, however, might increase interruptions of chest compressions and subsequently contribute to poor patient outcomes.¹⁵ Data on the duration of time between defibrillation attempts in response to changes in

WHAT IS ALREADY KNOWN ON THIS TOPIC

Resuscitation guidelines were revised in 2005 to recommend single shock protocols with two minutes of chest compressions between defibrillation attempts for persistent ventricular tachycardia/ventricular fibrillation (VT/VF)

Resuscitation guidelines for VT/VF were primarily informed by studies of cardiac arrest outside hospital and might not reflect optimal management of VT/VF arrest in hospital

WHAT THIS PAPER ADDS

Consistent with the adoption of resuscitation guidelines, the proportion of patients with a deferred second attempt at defibrillation (more than one minute between attempts) doubled from about 25% in 2004 to slightly more than 50% in 2012

Deferred second defibrillation was not associated with improved patient outcomes for those with VT/VF in hospital

resuscitation guidelines and its effect on survival for patients with cardiac arrest in hospital are lacking.

Understanding of the relation of timing of second defibrillation attempt for those with VT/VF in hospital has implications for the 40 000 patients who experience VT/VF in hospital each year.^{16 17} Using data from a large national quality improvement registry of cardiac arrest in hospital, we first examined temporal trends in the time interval between first and second attempts at defibrillation among patients with persistent VT/VF after the first attempt. We anticipated that the time interval between attempts would have increased in the past decade, consistent with adoption of single shock protocols in the management of VT/VF in hospital. We then examined the association between the time interval from first to second attempts at defibrillation and survival of patients to hospital discharge. As data on the timing of second attempts in relation to patients' outcomes are currently lacking for persistent VT/VF in hospital, any findings should provide empirical evidence to inform future resuscitation guidelines.

Methods

Study setting and design

We used data from the American Heart Association's (AHA) Get With The Guidelines-Resuscitation registry (GWTG-R). This is a large national prospective multi-center data registry and quality improvement program for cardiac arrest in hospital. Details regarding the registry design, data collection, and quality oversight have been described elsewhere.¹³ Briefly, participating hospitals in the United States voluntarily report data on all patients with a confirmed cardiac arrest (defined by the lack of a palpable central pulse, apnea, and unresponsiveness) who received cardiopulmonary resuscitation. Participating hospitals use multiple approaches to case finding to ensure complete capture of all cases of cardiac arrest in hospital, including review of cardiac arrest flow sheets and the hospital paging system logs, routine checks of code carts (carts stocked with emergency drugs and equipment) and pharmacy tracer drug records, and hospital billing charges for use of resuscitation drugs.¹⁷ At each facility, trained nurses/research coordinators abstract data from medical records and code review sheets using Utstein definitions for cardiac arrest in hospital.¹⁸ Accuracy of abstracted data is facilitated through certification of data entry personnel, data checks for missing or outlying observations, case study methods for newly enrolled hospitals prior to data submission, and periodic re-abstraction process. A random audit of the re-abstraction process showed a mean error rate of 2.4% (SD 2.7%) for all data.¹³ The AHA provides quality control and oversight for GWTG-R data collection, analysis, reporting, and research studies.

Patient population

We identified 30 500 patients aged 18 or older who received defibrillation for an index cardiac arrest in hospital in which the first identifiable rhythm was ventricular fibrillation or pulseless ventricular tachycardia at 615 hospitals participating in GWTG-R in 2004-12.

Among patients with multiple cardiac arrests during the same hospital admission, we included only the first event in the analysis. We excluded 1487 (4.9%) patients who received only one defibrillation attempt during the resuscitation event and 21 283 (69.8%) patients who were no longer in VT/VF after the first attempt (that is, the rhythm immediately after defibrillation was not VT/VF). Accordingly, our study also excludes patients with recurrent VT/VF as the time interval between defibrillation attempts in these patients is defined by the time of recurrent VT/VF, rather than the provider's treatment decision immediately after failed defibrillation.

Our eligible cohort therefore comprised 7730 patients who received a second defibrillation attempt for persistent VT/VF after an initial defibrillation attempt. From this cohort, we excluded 2764 (35.8%) patients in whom the time of the first or second defibrillation attempt was unknown. Comparison of standardized differences between patients with known and unknown defibrillation intervals were less than 5% for nearly all characteristics patients and arrests, suggesting that patients with available data on defibrillation time intervals were representative of the overall patient population (appendix, fig A). We excluded 154 (2.0%) patients with missing data on covariates used in risk adjusted analyses (that is, pre-existing conditions or interventions in place at the time of the intervention). We also excluded 1429 (18.5%) patients whose time from first to second defibrillation attempt was more than three minutes, given concerns that this prolonged interval was inconsistent with guidelines and could represent unusual resuscitation circumstances that could not be determined from the registry data. We further restricted our final analytic cohort to the 2733 patients at the 172 hospitals with adequate sample size (six or more eligible events) as we sought to examine outcomes by defibrillation intervals within hospitals (fig 1).

Patient involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in

Fig 1 | Flow and selection of patients in study of defibrillation time intervals and outcomes of cardiac arrest in hospital

developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. There are no plans to disseminate the results of the research to study participants or the relevant patient community. Results will be disseminated to hospitals participating in the GWTG-R through the AHA.

Time interval between defibrillation attempts

Defibrillation time within GWTG-R is captured in one minute intervals. Time between defibrillation attempts was calculated as the interval from the reported time of first attempt to the reported time of the second attempt. Both reported times were recorded in minutes and determined from documentation of cardiac arrest in the patient's medical records. As these data are captured from documentation of routine practice at hospitals participating in GWTG-R, the modality of time capture is not standardized across facilities. In our primary analysis, we used these data to determine proportion of patients in whom the second defibrillation attempt was early (defined as a time of a minute or less between first and second defibrillation) or deferred (defined as more than a minute between defibrillation attempts). As the time of defibrillation attempts in GWTG-R is recorded in minutes, we chose this categorization to reflect stacked shocks with minimal time delays between defibrillation attempts compared with single shock protocols with a period of chest compressions between defibrillation attempts. In secondary analyses, we classified patients according to whether the time between first and second defibrillation attempts was less than a minute, one minute, two minutes, or three minutes.

Study outcomes

Our primary outcome was survival to hospital discharge. Secondary outcomes included return of spontaneous circulation for at least 20 minutes after onset of the arrest, survival to 24 hours, and neurological status among those patients who survived to discharge as determined by cerebral performance category score (1=mild or no neurologic disability, 2=moderate neurologic disability, 3=severe neurologic disability, 4=coma or vegetative state, and 5=brain death). We dichotomized scores to assess for no major neurologic disability (score ≤ 2 at discharge) in relation to defibrillation time intervals.

Statistical analysis

We first evaluated temporal trends in the time between defibrillation attempts by calendar year with linear regression. We then compared characteristics of patients and arrests at baseline by early and deferred second defibrillation attempts using non-parametric Kolmogorov Smirnov test for continuous variables and χ^2 squared for categorical variables.

Our risk adjusted analysis used a multilevel propensity score weighting model, which accounts for the propensity to receive deferred defibrillation across hospitals. We determined this propensity from a non-parsimonious logistic regression model that

included 39 patient level covariates and accounted for hospital variation in the propensity for deferred second defibrillation attempts (appendix, table A).¹⁹ From the propensity score model, we calculated the stabilized inverse probability weight. We evaluated balance in the patients' covariates using standardized differences of the covariates between the early and deferred second defibrillation groups. After weighting, the maximum standardized difference was 7%, with most under 2.5%, much smaller than the commonly accepted adequate balance of 10% (appendix, fig B).²⁰ The outcome model included the main effect for the defibrillation time interval, weighted by the stabilized inverse probability weight. The sandwich estimator of the variance was used in estimating the standard error of the estimated main effect, to account for clustering of patients within hospitals and for modified Poisson estimation of relative risk. We then performed survival analyses using Kaplan-Meier curves and Cox model weighted on the inverse probability of treatment weights. Additional details of the propensity score weighted analysis are provided in the appendix.

As a sensitivity analysis, we used hierarchical modified Poisson regression,²¹ which uses a robust sandwich estimator to account for clustered observations by hospital and determined the risk adjusted association between deferred second defibrillation for persistent VT/VF and patient outcomes. Based on prior literature, our models adjusted for patient demographics (age, sex, race), diagnosis on admission (medical, cardiac; medical, non-cardiac; surgical, cardiac; surgical, non-cardiac; obstetric; trauma; other), pre-existing disorders at the time of arrest (acute stroke, baseline depression in central nervous system, hepatic insufficiency, hypotension, major trauma, metastatic cancer, septicemia, myocardial infarction this admission, none), therapeutic interventions in place at the time of cardiac arrest (assisted ventilation, invasive airway device, chest tube, monitoring with an arterial line, antiarrhythmic drugs, vasopressor, vasodilators), characteristics of the cardiac arrest (witnessed arrest, arrest location (intensive care unit, monitored unit, non-monitored unit, procedural area, other), time of arrest (daytime, night time, weekend), time to first defibrillation attempt), and calendar year.^{22,23} A full list of the variable specifications for covariates used in the multivariable models is provided in appendix table A.

Statistical analyses were performed with SAS/STAT software, version 9.4 of the SAS System for Windows and all statistical tests were evaluated $P \leq 0.05$.

Results

During the study period, the proportion of patients with deferred second defibrillation attempts increased from 26% (18/68) in 2004 to 57% (59/103) in 2012 ($P < 0.001$ for trend) (fig 2). In secondary analyses categorized by one minute intervals, there was a decrease in the proportion of patients with less than a minute between defibrillation attempts, from 31% (21/68) in 2004 to 8% (8/103) in 2012 (appendix, fig C). Over the same time period there was an increase in the proportion of patients with two

Fig 2 | Temporal trends in early (one minute or less) and deferred (more than one minute) defibrillation intervals in patients with cardiac arrest in hospital

minutes between defibrillation attempts from 22% (15/68) in 2004 to 33% (34/103) in 2012 and a similar increase in the proportion with three minutes between defibrillation attempts from 4% (3/68) in 2004 to 24% (25/103) in 2012. Exploratory analyses showed an increase in the proportion excluded from the cohort because of more than three minutes between defibrillation attempts (14.7% (22/150) in 2004 to 24.3% (111/457) in 2012), consistent with a temporal increase in time between defibrillation attempts (appendix, fig D).

Among 2733 patients with persistent VT/VF after the first defibrillation attempt, 1121 (41.0%) received a deferred second defibrillation attempt. Compared with patients who received an early second defibrillation attempt, patients with a deferred second attempts were less likely to have hypotension (20.3 v 25.6%, $P=0.001$), experience myocardial infarct during the current admission (24.6 v 29.0%, $P=0.01$), and more likely to have septicemia (14.7% v 9.9%, $P<0.001$). Time from onset of arrest to first defibrillation was longer in patients with deferred second defibrillation attempts (median time to defibrillation one versus two minutes, $P<0.001$) and patients with deferred second attempts were more likely to be in a non-monitored unit (11.2% v 9.1%, $P<0.001$) and less likely to be in procedural areas (26.8% v 73.2%, $P<0.001$) (table 1).

Achievement of return of spontaneous circulation occurred in 1651 patients (60.4%), while 1131 patients (41.4%) survived to 24 hours after cardiac arrest, and 772 (27.8%) survived to hospital discharge. Compared with early second defibrillation attempts, unadjusted patient outcomes were significantly worse after deferred second defibrillation attempts (57.4% v 62.5% for return of spontaneous circulation, 38.4% v 43.6% for survival to 24 hours, and 24.7% v 30.8% for survival to hospital discharge; $P<0.01$ for all comparisons). In risk adjusted analyses with propensity weighting methods for risk adjustment, a deferred second defibrillation attempt was not associated with survival to hospital discharge (adjusted risk ratio 0.89, 95% confidence interval 0.78 to 1.01; $P=0.08$). Similar results were observed in survival analyses (appendix, fig E). With hierarchical regression, a deferred second defibrillation attempt was not associated with survival to hospital discharge (0.92, 0.83 to 1.02; $P=0.12$). After risk adjustment, deferred

defibrillation was also not associated with return of spontaneous circulation or survival at 24 hours. Among patients who survived to hospital discharge, we observed similar findings for the association between deferred second defibrillation and the likelihood of having severe neurologic disability (propensity weighting adjusted risk ratio 0.94, 0.84 to 1.06) (table 2).

Discussion

In a large US national registry of cardiac arrest in hospital, we sought to describe temporal trends in time intervals between defibrillation attempts for persistent ventricular tachycardia or ventricular fibrillation (VT/VF) arrest and to determine the association between the timing of a second defibrillation attempt and patient outcomes. From 2004 to 2012, the proportion of patients with a deferred second defibrillation attempt (more than one minute between defibrillation attempts) doubled from about 25% to slightly more than 50%. Deferred second defibrillation, however, was not associated with improved patient outcomes. These findings stand in contrast to current resuscitation guidelines that emphasize two minutes of chest compressions between defibrillation attempts as optimal care for persistent VT/VF in hospital.⁸

Contemporary resuscitation guidelines were revised in 2005 on the basis of animal models and observational studies that showed the detrimental impact of prolonged interruptions in chest compressions resulting from stacked shocks in rapid succession.²⁻⁴ These prior studies, however, primarily reflect resuscitation outside hospital, including delays between onset of VT/VF and initiation of chest compressions and first defibrillation attempt. For example, animal model studies that supported single shock protocols evaluated initiation of resuscitation care after several minutes without cardiopulmonary resuscitation.²³⁻²⁵ Human studies supporting the use of single shock defibrillation protocols are from settings outside hospital,^{9,10} in which nearly half of arrests are unwitnessed with average delays of several minutes between recognition of arrest, initiation of cardiopulmonary resuscitation, and attempted defibrillation.²⁶ Whether the benefit of single shock protocols extends to settings in hospital, where cardiac arrests are often witnessed or monitored, initiation of cardiopulmonary resuscitation occurs rapidly, and time to first defibrillation is short, has not been previously explored.¹³ In fact, European Resuscitation Council guidelines suggest that stacked shocks can be considered for cardiac arrests occurring in certain witnessed or procedural settings.^{27,28} This guideline provision is consistent with a prior conceptual model of cardiac arrest that emphasizes the importance of defibrillation for rhythm termination in the early temporal phases of cardiac arrest.¹⁴ The findings from the current study agree with this conceptual model and suggest that greater emphasis on rhythm termination for persistent VT/VF might be warranted in hospital.

Notably, in our study, VT/VF was terminated with the first defibrillation attempt in under 70% of patients. This contrasts with prior small studies that have reported efficacy of first shock of >90% with VT/VF outside

Table 1 | Baseline characteristics by time interval between defibrillation attempts in patients with cardiac arrest in hospital. Figures are numbers (percentage) of patients unless otherwise specified

Characteristic	Second defibrillation attempt		P value
	Early (≤1 min between attempts) (n=1612, 59%)	Deferred (>1 min between attempts) (n=1121, 41%)	
Mean (SD) age (years)	64.22 (15.2)	65.22 (14.7)	0.09
Men	1059 (65.7)	733 (65.4)	0.9
White	1209 (75.0)	820 (73.2)	0.7
Pre-existing conditions:			
Heart failure this admission	277 (17.2)	193 (17.2)	0.9
Previous heart failure	307 (19.0)	243 (21.7)	0.09
Myocardial infarction this admission	467 (29.0)	276 (24.6)	0.01
Previous myocardial infarction	328 (20.4)	237 (21.1)	0.6
Arrhythmia	660 (40.9)	448 (40.0)	0.6
Hypotension	413 (25.6)	227 (20.3)	0.001
Respiratory insufficiency	559 (34.7)	376 (33.5)	0.5
Hepatic insufficiency	86 (5.3)	60 (5.4)	0.9
Metabolic or electrolyte abnormality	197 (12.2)	153 (13.7)	0.3
Diabetes mellitus	459 (28.5)	350 (31.2)	0.1
Baseline depression in CNS function	170 (10.6)	105 (9.4)	0.3
Acute stroke	50 (3.1)	44 (3.9)	0.3
Pneumonia	109 (6.8)	88 (7.9)	0.3
Septicemia	159 (9.9)	165 (14.7)	<0.001
Major trauma	55 (3.4)	33 (2.9)	0.5
Metastatic cancer	124 (7.7)	109 (9.7)	0.06
Interventions in place before arrest:			
Mechanical ventilation	592 (36.7)	368 (32.8)	0.04
Intravenous vasopressor medication	549 (34.1)	327 (29.2)	0.007
Dialysis	47 (2.9)	41 (3.7)	0.3
Intra-aortic balloon pump	72 (4.5)	31 (2.8)	0.02
Pulmonary artery catheter	105 (6.5)	49 (4.4)	0.02
Characteristics of cardiac arrest			
Initial cardiac arrest rhythm:			
Ventricular fibrillation	1029 (63.8)	741 (66.1)	0.2
Pulseless ventricular tachycardia	583 (36.2)	380 (33.9)	
Median time (mins) to first defibrillation attempt (IQR)	1 (0-4)	2 (0-5)	<0.001
Hospital location of arrest:			
Intensive care unit	418 (25.9)	343 (30.6)	<0.001
Monitored unit	168 (10.4)	190 (17.0)	
Non-monitored unit	146 (9.1)	126 (11.2)	
Procedural area	265 (73.2)	97 (26.8)	
Hospital-wide response activated	1141 (70.8)	817 (72.9)	0.2
Assessed with AED	287 (17.8)	248 (22.1)	0.01
Time of arrest:			
Arrest at night (11 pm to 7 am)	283 (17.6)	247 (22.0)	0.01
Arrest on weekend	429 (26.6)	275 (24.5)	
Hospital characteristics			
Geographic region:			
North and Mid-Atlantic	231 (14.3)	161 (14.4)	0.7
South Atlantic	403 (25.0)	268 (23.9)	
North central	369 (22.9)	243 (21.7)	
South central	287 (17.8)	224 (20.0)	
Mountain/Pacific	286 (17.7)	196 (17.5)	
Hospital size (No of beds):			
<250	229 (14.2)	154 (13.7)	0.3
250-499	741 (46.0)	463 (41.3)	
≥500	606 (37.6)	475 (42.4)	
AED=automated external defibrillator, CNS=central nervous system, IQR=interquartile range.			

AED=automated external defibrillator, CNS=central nervous system, IQR=interquartile range.

hospital.²⁹⁻³³ As a result of these prior studies, guideline writing committees have raised concerns about the incremental benefit of an immediate second defibrillation attempt relative to resumption of chest compressions.^{6,7} Our study suggests persistent VT/VF is pertinent for a larger proportion of VT/VF in hospital than would be expected from prior studies of cardiac arrest outside hospital. As a result, understanding the appropriate

hospital. As a result, understanding the appropriate

Table 2 | Survival and neurologic outcomes by time interval between defibrillation attempts in patients with cardiac arrest in hospital

Outcome	No (%) with second defibrillation attempt		Risk ratio (95% CI)		
	Early	Deferred	Unadjusted	Propensity weighted adjusted	Hierarchical regression adjusted
Survival outcomes					
Return of spontaneous circulation	1008/1612 (62.5)	643/1121 (57.4)	0.92 (0.86 to 0.98)	0.94 (0.88 to 1.01)	0.95 (0.90 to 1.01)
Survival to 24 hours	701/1606 (43.6)	430/1121 (38.4)	0.88 (0.80 to 0.96)	0.93 (0.84 to 1.03)	0.95 (0.87 to 1.04)
Survival to discharge	495/1605 (30.8)	277/1121 (24.7)	0.80 (0.71 to 0.91)	0.89 (0.78 to 1.01)	0.92 (0.83 to 1.02)
Neurologic outcome (survivors only)					
No major disability	306/443 (69.1)	152/236 (64.4)	0.93 (0.83 to 1.04)	0.94 (0.83 to 1.06)	0.98 (0.88 to 1.10)

balance between defibrillation for rhythm termination and minimization of interruptions to chest compression could have even greater implications for in hospital.

Despite a lack of data on single shock defibrillation protocols in hospital, we observed a significant temporal increase in the proportion of deferred second defibrillation attempts from 2004 to 2012. This is consistent with adoption of 2005 resuscitation guidelines and greater use of single shock protocols with a period of chest compressions between defibrillation attempts. Several studies from settings outside hospital have shown improvement in patient outcomes with adoption of guideline changes, which included single shock protocols for defibrillation of VT/VF.^{10 11} A randomized trial that compared stacked and single shock protocols outside hospital, however, failed to show improved patient outcomes with single shock defibrillation.¹²

Overall temporal trends in survival after VT/VF arrest in hospital have improved in the past decade and could reflect the impact of changes in resuscitation care in accordance with resuscitation guidelines.¹⁷ It is important to note, however, that guideline revisions were not restricted to defibrillation protocols but also highlighted minimizing interruptions in chest compression for the placement of invasive airways or invasive lines and the importance of avoiding excessive ventilation.^{6 7} Our findings do not conflict with the benefit of these guideline recommendations overall but raise questions about the specific benefit of deferred second defibrillation attempts for VT/VF in hospital.

Strengths and limitations

Strengths of the current study include the use of national multicenter data from a well established registry of cardiac arrest in hospital with high data quality. Our results, however, should also be considered in light of the following limitations. Although we used multiple methods for risk adjustment in the comparison of outcomes by defibrillation interval, we cannot exclude the possibility of unmeasured confounding in this observational study. Second, in the registry the time interval between defibrillation attempts is captured in minutes, and this limits the ability to evaluate the association between defibrillation time intervals and patient outcomes by smaller units of time. Furthermore, we cannot exclude misclassification of time intervals related to challenges of exact documentation of event times during care of patients who have cardiac arrest in hospital; although, we would expect this to bias our results towards the null in the absence of differential misclassification. Third, we lacked data on other aspects of

quality of cardiopulmonary resuscitation, including frequency and duration of chest compressions or compression rate, depth, and hands-off time—factors known to correlate with patient outcomes. Fourth, as arrests in hospital in our study were often monitored or witnessed, our findings might be less applicable to health systems with lower use of inpatient monitoring and longer times to recognition of arrest. Similarly, the association between defibrillation intervals and patient outcomes might be influenced more by the time to arrest recognition and treatment than the event setting (that is, in hospital versus outside hospital). We were, however, unable to identify patients with delayed recognition of VT/VF arrest within the registry to further explore this relation. Finally, we lacked data on whether stacked or single shock defibrillation protocols were used in the care of these registry patients and instead used the time interval between first and second defibrillation attempts as our measure of defibrillation practice. The increasing prevalence of deferred second defibrillation after publication of the 2005 resuscitation guidelines suggests these time intervals are a reasonable measure of defibrillation practice.

Conclusion

The time interval between defibrillation attempts for persistent VT/VF in hospital has increased in the past decade. These findings are consistent with adoption of resuscitation guidelines that support single shock protocols with chest compressions between defibrillation attempts. Deferred defibrillation for persistent VT/VF, however, was not associated with improved survival. Further study is necessary to understand whether current guidelines, which recommend against immediate second defibrillation attempts for persistent VT/VF in hospital, need reconsideration.

Get With The Guidelines-Resuscitation Adult Task Force

SMB, PSC, Saket Girotra (University of Iowa Carver College of Medicine); Michael W Donnino (Beth Israel Deaconess Medical Center); Dana P Edelson (University of Chicago); Robert T Faillace (Geisinger Healthcare System); Romergryko Geocadin (Johns Hopkins University School of Medicine); Raina Merchant (University of Pennsylvania School of Medicine); Vincent N Mosesso (University of Pittsburgh School of Medicine); Joseph P Ornato and Mary Ann Peberdy (Virginia Commonwealth University).

Contributors: SMB was responsible for conception, design, analysis, data interpretation, and manuscript writing. WL and GKG analyzed and interpreted data and wrote the manuscript. PSC, BKN, and PMH designed the study, interpreted data, and wrote the manuscript. AS, CS, PDV, MLA, and PMS interpreted data and wrote the manuscript. SMB had full access to all data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis and is guarantor.

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Ethical approval: This study was approved by the Colorado multiple institutional review board.

Data sharing: No additional data available. Requests for GWTG-R data are managed by the American Heart Association (http://www.heart.org/HEARTORG/HealthcareResearch/Healthcare-Research_UCM_001093_SubHomePage.jsp).

Transparency: The lead author affirms that this manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant) have been explained.

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Appendix: Supplementary figures, text, and table