

Delayed Time to Defibrillation after Intraoperative and Periprocedural Cardiac Arrest

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ABSTRACT

Background: Delay in defibrillation (more than 2 min) is associated with worse survival in patients with a cardiac arrest because of ventricular fibrillation or pulseless ventricular tachycardia in intensive care units and inpatient wards.

Methods: We tested the relationship between delayed defibrillation and survival from intraoperative or periprocedural cardiac arrest, adjusting for baseline patient characteristics. The analysis was based on data from 865 patients who had intraoperative or periprocedural cardiac arrest caused by ventricular fibrillation or pulseless ventricular tachycardia in 259 hospitals participating in the National Registry of Cardiopulmonary Resuscitation.

Results: The median time to defibrillation was less than 1 min (interquartile range, <1 to 1 min). Delays in defibrillation occurred in 119 patients (13.8%). Characteristics associated with delayed defibrillation included pulseless ventricular tachycardia and noncardiac admitting diagnosis. The association between delayed defibrillation and survival to hospital discharge differed for periprocedural and intraoperative cardiac arrests (P value for interaction = 0.003). For patients arresting outside the operating room, delayed defibrillation was associated with a lower

probability of surviving to hospital discharge (31.6% *vs.* 62.1%, adjusted odds ratio 0.49; 95% CI 0.27, 0.88; $P = 0.018$). In contrast, delayed defibrillation was not associated with survival for cardiac arrests in the operating room (46.8% *vs.* 39.6%, adjusted odds ratio 1.23, 95% CI 0.70, 2.19, $P = 0.47$).

Conclusions: Delays in defibrillation occurred in one of seven cardiac arrests in the intraoperative and periprocedural arenas. Although delayed defibrillation was associated with lower rates of survival after cardiac arrests in periprocedural areas, there was no association with survival for cardiac arrests in the operating room.

What We Already Know about This Topic

- ❖ For patients with ventricular cardiac arrest, delayed defibrillation is associated with worse survival in numerous hospital and nonhospital settings.

What This Article Tells Us That Is New

- ❖ Data from the National Registry of Cardiopulmonary Resuscitation suggest that delayed defibrillation is associated with lower hospital survival for patients with periprocedural, but not intraoperative ventricular cardiac arrest.

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DEFIBRILLATION within 2 min has been shown to predict survival after ventricular fibrillation or pulseless ventricular tachycardia among patients whose cardiac arrest occurred while they were in intensive care units or inpatient beds.¹ Current recommendations are that hospitalized patients receive defibrillation therapy within 2 min after recognition of cardiac arrest.^{2,3}

Intraoperative and periprocedural cardiac arrests occur in a unique clinical setting where resuscitation response times and underlying etiology may differ from cardiac arrests occurring

◇ This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 9A.

◆ This article is accompanied by an Editorial View. Please see: Mahajan A, Hoftman N: To beat or not to beat: Is timing the only question? Survival after delayed defibrillation. ANESTHESIOLOGY 2010; 113:765-6.

elsewhere in the hospital.⁴ A monograph from the American Society of Anesthesiology Committee on Critical Care Medicine notes that perioperative cardiac arrest is usually witnessed, frequently anticipated, and relatively rare when compared with arrest in other locations. Given a paucity of data specific to the perioperative setting, the monograph calls for “systematic study of how to manage these rare events.”⁵ Little is known regarding the relationship between defibrillation response times and outcomes of intraoperative and periprocedural cardiac arrest. Patients who develop pulseless ventricular tachycardia or ventricular fibrillation arrest in the cardiac intervention suites may be more responsive to rapid defibrillation because of the nature of the ongoing procedure (e.g., catheter ablation, coronary angiography). Alternatively, patients who arrest in the operating room as a result of intraoperative hemorrhage may have a poor prognosis regardless of resuscitation measures such as defibrillation time.⁵ A recent study that examined the relationship between time to defibrillation and survival for pulseless ventricular tachycardia or ventricular fibrillation arrests excluded patients experiencing cardiac arrest in the operating room, perianesthesia care unit (PACU), and interventional procedure areas.¹

Accordingly, the primary purpose of this analysis was to examine the association between time to defibrillation and survival for intraoperative and periprocedural patients with cardiac arrest whose first pulseless rhythm is identified as pulseless ventricular tachycardia or ventricular fibrillation.

Materials and Methods

Data Collection and Integrity

In 2000, the American Heart Association established the National Registry of Cardiopulmonary Resuscitation (NRCPR) to assist participating hospitals with systematic data collection on resuscitative efforts. The NRCPR is a prospective, observational, multicenter registry of in-hospital cardiac arrests. Hospitals join voluntarily and pay a fee for data support and quarterly quality improvement reports. The registry is currently the largest repository of information on in-hospital cardiopulmonary arrest,⁶ with close to 175,000 cardiopulmonary arrest events recorded as of September 30, 2009.^{||} The members of the American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators are listed in appendix 1.

In-hospital resuscitation teams typically assign a clinical provider to serve in a data-recording role during the resuscitation event. These individuals log the event for clinical documentation purposes, using local documentation processes, and the event logs are stored with the patient's hospital medical record.

Hospital medical records of sequential cardiac arrests are abstracted electronically at each institution by trained NRCPR-certified research coordinators who are typically not involved in the resuscitation event. Data elements use standardized Utstein

nomenclature to facilitate consistent definitions of variables across multiple sites.⁷ Data abstractors are required to complete a certification exam successfully. These exams comprise evaluation of data abstraction, entry accuracy, and operational definition compliance before a site is allowed to submit data to the NRCPR. In addition, the data entry software (provided by Digital Innovation, Inc., Forest Hill, MD, 2008) has more than 300 checks and smart skips to assist with accurate data entry. Participating hospitals are required to submit 10% of their resuscitation forms so that reabstraction can be performed by NRCPR personnel. The NRCPR has completed a periodic audit of the accuracy of the data elements, including time variables, and the most recent error rate for all variables was less than 3%.⁸ Other efforts to ensure data accuracy include ongoing abstractor training with monthly users' group calls and an annual users' group conference.

Each patient is assigned a unique, deidentified database number before data entry and transmission to the central NRCPR database in compliance with the Health Insurance Portability and Accountability Act. On behalf of the NRCPR, Digital Innovation, Inc., provides data management and quarterly reports summarizing individual hospital data and comparative group reports. Oversight is provided by the American Heart Association, represented by a scientific advisory board and an executive database steering committee.

Six major categories of variables for each patient with a cardiac arrest are collected: (1) facility data; (2) patient demographic data; (3) preevent data; (4) event data; (5) outcome data; and (6) process quality improvement data.

Study Design

The initial study population included adults 18 yrs and older who experienced a pulseless cardiac arrest caused by pulseless ventricular tachycardia or ventricular fibrillation in the operating room, PACU, diagnostic suite, or cardiac intervention suite. All events were reported from 1 of the 413 facilities in the United States and Canada that provided at least 6 months of data to the NRCPR between January 1, 2000, and February 11, 2008. To be included in the registry, the event had to elicit a resuscitation response by facility personnel and to have had a resuscitation record completed. To evaluate the impact of delayed defibrillation, only patients whose first identified rhythm was pulseless ventricular tachycardia or ventricular fibrillation were included in the analysis ($n = 1,131$).

For patients having multiple cardiac arrests during the same hospitalization, only the first in-hospital cardiac arrest event was analyzed, and recurrent arrests ($n = 59$) were excluded (fig. 1). Further exclusions comprised patients with an implanted cardioverter-defibrillator ($n = 25$), prior Do-not-resuscitate orders ($n = 9$), and missing or inconsistent data on the time of the cardiac arrest ($n = 173$). The final study cohort included 865 patients who experienced cardiac arrest in 259 facilities.

Primary Process of Care Variable

Time to defibrillation, the primary process of care variable, was calculated as the interval from the reported time of initial recog-

§ Available at: www.asahq.org/clinical/Anesthesiology-Centric-ACLS.pdf. Accessed May 10, 2010.

|| Available at: <http://www.nrcpr.org/>. Accessed January 19, 2010.

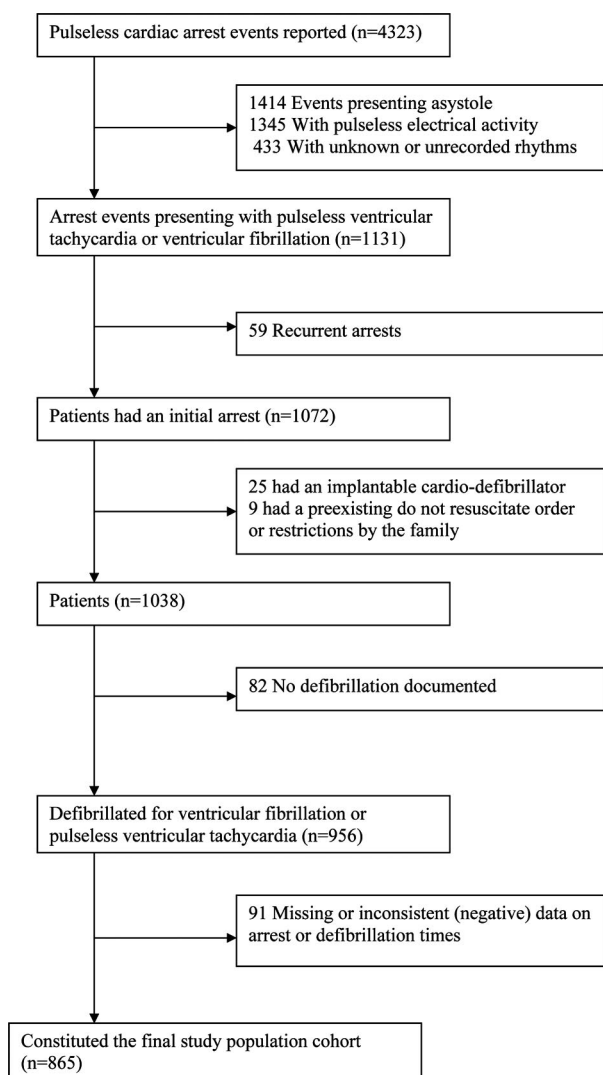


Fig. 1. Exclusion criteria and final study cohort.

nition of cardiac arrest to the reported time of first attempted defibrillation. Both times were determined from cardiac arrest documentation in the patient's medical record and were recorded in minutes. These data were used to determine the proportion of study subjects with delayed defibrillation, which was defined, based on prior work and current guidelines,^{1,6} as a time to defibrillation greater than 2 min.

Statistics

The primary outcome was survival to hospital discharge. Unadjusted analyses evaluated baseline differences between patients with and without missing time data and between patients with and without delayed defibrillation using the Student *t* test for continuous variables and the Pearson chi-square test or the Fisher exact test for categorical variables, as appropriate. To distinguish between random and informative missing time data, a multivariable logistic regression model was built to predict time to defibrillation, controlling for age, sex, and race; bivariate analyses of potential predictor variables with and without

missing time to defibrillation were entered into this regression model based on an α level of 0.05.

A multivariable logistic regression model was then constructed to investigate the relationship between delayed defibrillation and survival to discharge. Collinearity diagnostics were performed for all study covariates before model development. A generalized estimating equation with an exchangeable correlation matrix was used to control for clustering at the facility level. Independent variables included age, sex, race (white *vs.* non-white), presenting rhythm (ventricular fibrillation or pulseless ventricular tachycardia), location of arrest (the operating room, PACU, cardiac catheterization laboratory, or diagnostic suite), arrest in the operating room (*vs.* all other locations), admitting diagnosis (cardiac *vs.* noncardiac), and weekday arrests (7:00 AM until 11:00 PM Monday through Friday *vs.* arrests during all other times).⁹

Event survival, defined as a return of spontaneous circulation for at least 20 min from the initial resuscitation event, was a secondary outcome. Following the analytic steps described above, a multivariable logistic regression model was constructed to examine the relationship between delayed defibrillation and event survival.

Additional multivariable logistic regression models were used to evaluate statistical interactions between delayed defibrillation time and cardiac arrest location, between delayed defibrillation and a diagnosis of myocardial infarction during the current hospitalization, and between delayed defibrillation and preexisting hemorrhage on survival outcomes. In cases where a significant interaction ($P < 0.05$) was found, the final models explored the relationship between delayed defibrillation and survival outcomes within these subgroups. Hemorrhage is not recorded in the NRCPR. We therefore defined hemorrhage as existing if a patient received any blood product transfusion or aortic cross-clamping or had preexisting hypotension or hypoperfusion but no acute non-stroke event, acute stroke, sepsis, pneumonia, myocardial infarction, or congestive heart failure in the current admission. The models were constructed as above using generalized estimating equations, with separate models constructed for all patients arresting in the operating room, all patients arresting in the cardiac catheterization laboratory, those with and those without preexisting hemorrhage, and those with and those without a diagnosis of myocardial infarction.

Finally, a simple logistic regression model was used to estimate the effect size of each additional minute of delay in defibrillation on survival to discharge.

For all analyses, the null hypothesis was evaluated at a two-sided significance level of 0.05, and effect sizes were reported as odds ratios (OR) or adjusted odds ratios (AOR), both with 95% confidence intervals (CIs). All statistical analyses were performed using Stata, Version 10, 2006 (Stata-Corp LP, College Station, TX).

Results

Exclusions are illustrated in figure 1. The 91 patients (9.4%) who were excluded because their records were missing time to

Table 1. Event Characteristics According to Time to Defibrillation

Characteristic	≤2 Min to Defibrillation (n = 746)	>2 Min to Defibrillation (n = 119)	P Value
Age, year (mean ± SD)	63.6 ± 15.6	65.1 ± 17.0	0.36
Male sex, No. (%)	497 (66.6)	69 (58.0)	0.07
White race*, No. (%)	584 (78.3)	91 (76.5)	0.66
Pulseless ventricular tachycardia†, No. (%)	195 (26.1)	50 (42.0)	<0.001
Event location, No. (%)			<0.001
Operating room or same-day surgery center	309 (41.4)	64 (53.8)	
Perianesthesia care unit	122 (16.4)	23 (19.3)	
Cardiac catheterization laboratory	251 (33.7)	13 (10.9)	
Diagnostic suite	64 (8.6)	19 (16.0)	
Illness category, No. (%)			<0.001
Medical, cardiac	284 (38.0)	20 (16.8)	
Medical, noncardiac	54 (7.2)	22 (18.5)	
Surgical, cardiac	121 (16.2)	12 (10.1)	
Surgical, noncardiac	261 (35.0)	60 (50.4)	
Other (trauma or obstetric)	26 (3.4)	5 (4.2)	
Time of cardiac arrest, No. (%)			
After hours‡	168 (22.6)	19 (16.0)	0.11
Nighttime 23:00–7:00	77 (10.3)	7 (5.9)	0.13
Saturday or Sunday daytime 7:00–23:00	91 (12.2)	12 (10.1)	0.51
Preexisting conditions, No. (%)			
Data on preexisting conditions not collected	79 (10.6)	9 (7.6)	0.31
Congestive heart failure at admission	69 (10.3)	14 (12.7)	0.45
Previous congestive heart failure	106 (15.9)	20 (18.2)	0.55
Myocardial infarction at admission	215 (32.2)	19 (17.3)	0.002
Previous myocardial infarction	140 (21.0)	19 (17.3)	0.37
Respiratory insufficiency	175 (26.2)	31 (28.2)	0.67
Renal insufficiency	124 (18.6)	27 (24.6)	0.14
Hepatic insufficiency	12 (1.8)	1 (0.9)	0.50
Metabolic or electrolyte derangement	71 (10.6)	11 (10.0)	0.84
Diabetes mellitus	164 (24.6)	31 (28.2)	0.42
Baseline central nervous system deficit	55 (8.3)	8 (7.3)	0.73
Acute stroke	15 (2.3)	1 (0.9)	0.36
Acute nonstroke neurologic disorder	28 (4.2)	6 (5.5)	0.55
Pneumonia	12 (1.8)	7 (6.4)	0.004
Sepsis	36 (5.4)	7 (6.4)	0.68
Hemorrhage§	116 (17.1)	20 (17.9)	0.85
Major trauma	37 (5.6)	4 (3.6)	0.41
Cancer	43 (6.5)	11 (10.0)	0.18
Immediate cause of arrest, No. (%)			
Data on immediate cause of arrest not collected	40 (5.4)	1 (0.8)	0.03
Active myocardial ischemia or evolving myocardial infarction	123 (17.4)	12 (10.2)	0.05
Acute pneumothorax	4 (0.6)	0	0.41
Acute pulmonary edema	6 (0.9)	2 (1.7)	0.39
Acute pulmonary embolism	7 (1.0)	2 (1.7)	0.50
Acute respiratory insufficiency	110 (15.6)	22 (18.6)	0.40
Acute stroke	1 (0.1)	1 (0.9)	0.15
Arrhythmia (excluding sinus tachycardia)	560 (79.3)	99 (83.9)	0.25
Conscious/procedural sedation	31 (4.4)	2 (1.7)	0.17
Hypotension/hypoperfusion	243 (34.4)	38 (32.2)	0.64
Hypothermia	2 (0.3)	0	0.56
Inadequate or obstruction of invasive airway	5 (0.7)	0	0.36
Inadequate or obstruction of natural airway	13 (1.8)	2 (1.7)	0.91
Status epilepticus	2 (0.3)	0	0.56
Metabolic or electrolyte abnormality	43 (6.1)	4 (3.4)	0.24
Adverse drug effect or reaction	6 (0.9)	0	0.32
Continuous infusions in place, No. (%)			
Data on continuous infusions not collected, No. (%)	46 (6.2)	2 (1.7)	0.05
Epinephrine	40 (5.7)	9 (7.7)	0.40
Lidocaine	21 (3.0)	2 (1.7)	0.44
Amiodarone	35 (5.0)	4 (3.4)	0.46

(continued)

Table 1. Continued

Characteristic	≤2 Min to Defibrillation (n = 746)	>2 Min to Defibrillation (n = 119)	P Value
Electrocardiographic monitoring in place at the time of arrest, No. (%)			
Operating room	299 (96.8)	59 (92.2)	0.09
Perianesthesia care unit	117 (95.9)	20 (87.0)	0.09
Cardiac catheterization laboratory	250 (99.6)	13 (100.0)	0.82
Diagnostic suites	46 (71.9)	16 (84.2)	0.28
Survived event, No. (%)	541 (72.5)	71 (59.7)	0.004
Survived to discharge, No. (%)	396 (53.1)	47 (39.5)	0.006

* Race was determined by the hospital investigators. White race was compared with all others, including American Indian/Eskimo/Aleutian, Asian/Pacific Islander, Black, Other, Unknown. † Pulseless ventricular tachycardia was compared with ventricular fibrillation. ‡ After hours encompassed both nighttime and weekend days. § Hemorrhage defined if the patient received any blood product transfusion or aortic cross-clamping or had preexisting hypotension or hypoperfusion without an acute nonstroke event, acute stroke, sepsis, pneumonia, myocardial infarction, or congestive heart failure in the current admission.

defibrillation had baseline characteristics that were similar to those patients in the final study cohort, except that the excluded patients were younger, more likely to present in the operating room as opposed to other locations, with a cardiac surgical or traumatic illness category, with preexisting hemorrhage or major trauma, or arrest attributed to conscious sedation or hypotension (appendix 2). Excluded patients were less likely to survive the event (55.9% *vs.* 70.8%, OR 0.48, 95% CI 0.31, 0.75, $P = 0.001$) or to survive until hospital discharge (33.0% *vs.* 51.2%, OR 0.47, 95% CI 0.30, 0.74, $P = 0.001$). Multivariable analysis confirmed that three variables were associated with missing time information: arrests in the operating room, arrests attributed to conscious sedation, and arrests attributed to arrhythmia (appendix 3).

Of the 865 patients included in the study cohort, 373 (43.1%) arrested in an operating room, 145 (16.7%) in the PACU, 264 (30.5%) in a cardiac catheterization laboratory, and 83 (9.6%) in a diagnostic suite. The majority of patients had cardiac rhythm monitoring in place at the time of the arrest (358 [96.0%] in the operating room, 137 [94.5%] in the PACU, 263 [99.6%] in the cardiac catheterization laboratory, and 62 [74.7%] in the diagnostic suite, $P < 0.001$). The overall median time to defibrillation was less than 1 min (interquartile range, <1 to 1 min), with 119 patients (13.8%) noted to have delayed defibrillation (more than 2 min from cardiac arrest to defibrillation). A higher proportion of patients with delayed defibrillation were admitted with noncardiac diagnoses and presented in pulseless ventricular tachycardia in the operating room or diagnostic suite (table 1). In adjusted analyses, a presenting rhythm of pulseless ventricular tachycardia and a noncardiac admitting diagnosis were independently associated with delays in defibrillation (table 2).

In bivariate analyses, delayed defibrillation was associated with lower event survival (60% *vs.* 72.5%, OR 0.62, 95% CI 0.42, 0.92, $P = 0.02$) and lower survival to discharge (39.5% *vs.* 53.1%, OR 0.67, 95% CI 0.46, 0.98, $P = 0.04$).

In predicting event survival, significant interactions were found between delayed defibrillation and arrest in the operating room as opposed to other locations (adjusted $P = 0.022$), be-

tween delayed defibrillation and preexisting diagnosis of myocardial infarction during the current hospitalization ($P = 0.009$), and between delayed defibrillation and preexisting diagnosis of hemorrhage during the current admission ($P = 0.028$). In predicting survival to discharge, significant interactions were found between delayed defibrillation and location of arrest (arrest in the operating room as opposed to other locations) (adjusted $P = 0.003$), between delayed defibrillation and a preexisting diagnosis of myocardial infarction during the current hospitalization ($P = 0.008$), and between delayed defibrillation and a preexisting diagnosis of hemorrhage during the current admission ($P = 0.003$). Because of the significant interactions, we evaluated the relationships of delayed defibrillation with survival outcomes separately for periprocedural and intraoperative cardiac arrests, for patients with and without preexisting myocardial infarction, and for patients with and without preexisting hemorrhage.

Among patients arresting outside of the operating room (in the cardiac catheterization laboratory, the diagnostic suites, or the PACU), delayed defibrillation was independently associated with lower event survival (52.6% *vs.* 78.1%, AOR 0.44, 95% CI 0.25, 0.79, $P = 0.006$) and lower survival to discharge (31.6% *vs.* 62.1%, AOR 0.49, 95% CI 0.27, 0.88, $P = 0.018$) (table 3). Other significant predictors of survival to discharge for periprocedural arrests included patient age, male sex, and a cardiac admission diagnosis.

Table 2. Independent Predictors of Delayed Time to Defibrillation (n = 865)

Variable	Adjusted Odds Ratio (95% CI)	P Value
Pulseless ventricular tachycardia (n = 245)	1.79 (1.18, 2.70)	0.006
Cardiac patient, surgical or medical (n = 437)	0.47 (0.28, 0.80)	0.006

Controlling for patient age, sex, race, time, and location of arrest. CI = confidence interval.

Table 3. Association between Delayed Defibrillation and Survival by Arrest Location (n = 865)

Variable	Survived Event				Survived to Discharge			
	Operating Room n/N = 380/505 (75.2%)		Procedural Areas* n/N = 232/360 (64.4%)		Operating Room n/N = 296/505 (58.6%)		Procedural Areas n/N = 147/360 (40.8%)	
	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value
Delayed defibrillation† (n = 119)	0.95 (0.52, 1.75)	0.876	0.44 (0.25, 0.79)	0.006	1.23 (0.70, 2.19)	0.471	0.49 (0.27, 0.88)	0.018
Age	1.00 (0.98, 1.01)	0.468	0.98 (0.97, 0.99)	0.007	0.98 (0.97, 1.00)	0.020	0.97 (0.96, 0.99)	<0.001
Male sex (n = 566)	0.44 (0.27, 0.71)	0.001	1.14 (0.75, 1.73)	0.526	0.66 (0.42, 1.04)	0.073	1.49 (1.02, 2.17)	0.038
White race‡ (n = 675)	1.62 (0.96, 2.74)	0.071	0.86 (0.52, 1.42)	0.550	1.48 (0.88, 2.50)	0.139	0.93 (0.59, 1.47)	0.765
Cardiac patient (medical or surgical)§ (n = 437)	1.87 (1.08, 3.25)	0.026	1.27 (0.82, 1.97)	0.283	1.79 (1.09, 2.96)	0.021	1.57 (1.05, 2.35)	0.029
Weekday or evening arrest (n = 677)	1.62 (0.95, 2.78)	0.077	1.04 (0.66, 1.66)	0.858	2.09 (1.17, 3.71)	0.012	1.22 (0.81, 1.84)	0.351
Ventricular fibrillation (n = 620)	0.81 (0.50, 1.31)	0.391	1.00 (0.64, 1.58)	0.993	0.81 (0.51, 1.29)	0.382	1.46 (0.97, 2.21)	0.072

* Procedural areas included the cardiac catheterization laboratory, diagnostic suites, and postanesthesia care unit. † Delayed defibrillation is more than 2 min from the time of pulselessness until the time of defibrillation. ‡ Race was determined by the hospital investigators. White race was compared with all others, including American Indian/Eskimo/Aleutian, Asian/Pacific Islander, Black, Other, Unknown. § Cardiac medical or surgical patients were compared with patients classified as noncardiac medical or surgical, trauma, or obstetric. || Weekday or evening arrests took place between 7:00 AM and 11:00 PM Monday through Friday.

CI = confidence interval.

The effect on event survival was also evident in a subanalysis of patients arresting in the cardiac catheterization laboratory, where 20 patients (6.6%) received delayed defibrillation. Event survival for these patients was reduced (45.0% *vs.* 81.7%, AOR 0.27, 95% CI 0.1, 0.69, $P = 0.006$) when compared with survival among catheterization patients with prompt defibrillation. The effect on survival to discharge was also significant (35.0% *vs.* 68.7%, AOR 0.38, 95% CI 0.15, 0.98, $P = 0.05$). Because of collinearity, cardiac admission diagnosis was excluded from the list of independent variables for the model specific to the cardiac catheterization laboratory.

Among patients who arrested in the operating room, there was no difference between delayed defibrillation and event survival (66.1% *vs.* 64.1%, AOR 0.95, 95% CI 0.52, 1.75, $P = 0.88$) or survival to discharge (46.8% *vs.* 39.6%, OR 1.23, 95% CI 0.70, 2.19, $P = 0.47$). For these arrests, independent predictors of survival to discharge included patient age, a cardiac admission diagnosis, and time of arrest, but not delayed defibrillation (table 3).

In areas outside of the operating room, each additional minute of delay in defibrillation produced a nonsignificant trend toward reduced survival. This trend was not apparent among arrests in the operating room (fig. 2).

Among patients with a preexisting diagnosis of myocardial infarction during the current admission, delayed defi-

brillation was independently associated with lower event survival (36.8% *vs.* 79.1%, AOR 0.19, 95% CI 0.07, 0.52, $P = 0.001$) and lower survival to discharge (15.8% *vs.* 59.5%, AOR 0.16, 95% CI 0.05, 0.59, $P = 0.005$) (table 4).

For arrests among the 136 patients with hemorrhage, none of the independent variables predicted survival to discharge in multivariable analysis (table 5). In bivariate analysis, delayed defibrillation was not associated with a change in event survival (65.0% *vs.* 53.5%, $P = 0.34$) or survival to discharge (45.0% *vs.* 24.1%, $P = 0.05$).

A preexisting diagnosis of myocardial infarction during the current admission was most common in the cardiac catheterization laboratory (140 [53.0%], compared with 18 [21.7%] in a diagnostic suite, 31 [13.3%] in the PACU, and 45 [12.1%] in the operating room, $P < 0.001$). A preexisting diagnosis of hemorrhage was most common in the operating room (101 [27.1%], compared with 20 [13.8%] in the PACU, 6 [7.2%] in the diagnostic suite, and 9 [6.6%] in the cardiac catheterization laboratory, $P < 0.001$).

Discussion

Primary Findings

In this large, multisite registry of in-hospital cardiac arrests, we found that delays in defibrillation occurred even in the intraop-

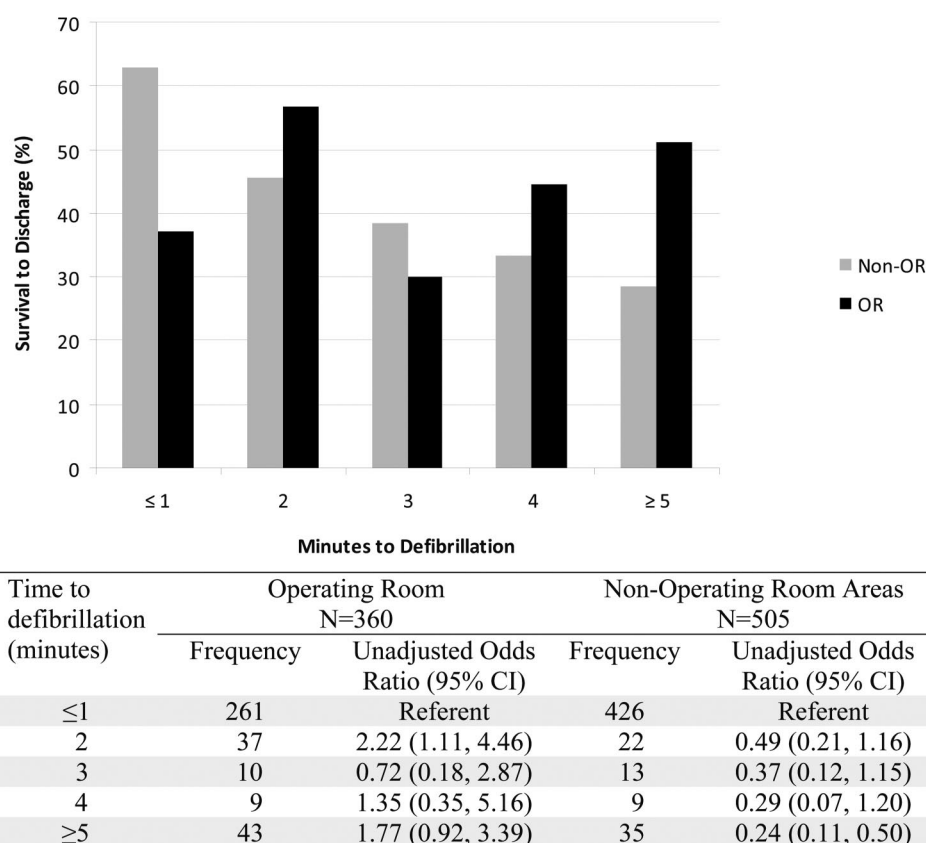


Fig. 2. Unadjusted rates of survival to hospital discharge according to time to defibrillation and event location. CI = confidence interval; OR = operating room.

erative and periprocedural arenas where multiple medical and nursing staff are typically present. Delays in therapeutic defibrillation impacted 13.8% of resuscitations and were more frequent in patients presenting in pulseless ventricular tachycardia and in patients admitted for a noncardiac diagnosis. For patients arresting in periprocedural areas, including the cardiac catheterization laboratory, the diagnostic suites, and the PACU, these delays were associated with lower rates of survival through the initial resuscitation and to hospital discharge.

A number of studies have demonstrated that increased time to defibrillation decreases survival for patients suffering from out-of-hospital cardiac arrest with ventricular fibrillation or pulseless ventricular tachycardia.^{10–17} This relationship has more recently been confirmed among patients experiencing in-hospital ventricular arrest, with events drawn primarily from hospital wards and intensive care units.^{1,18–21} Skrifvars *et al.* included 3 patients suffering from pulseless ventricular tachycardia in the operating area among a sample of 57 patients with shockable rhythms throughout the hospital, and found that survivors had a shorter time interval to defibrillation compared with nonsurvivors (median 1 min *vs.* 5 min, $P = 0.046$). Twelve of 206 arrests reported by Hajbaghery *et al.* were identified in operating rooms or surgical wards, but further details, such as the presenting rhythm for these 12 arrests, were not provided.²¹

Using data from the NRCPR, Chan *et al.* examined the relationship between time to defibrillation for ventricular fibrillation and pulseless ventricular tachycardia arrests and survival

to discharge among patients in intensive care units and general care beds.¹ A graded inverse association was found between time to defibrillation and unadjusted survival across a broad range of time thresholds. The accompanying editorial concluded that survival after cardiac arrest caused by ventricular tachycardia or ventricular fibrillation requires prompt defibrillation, regardless of the setting in which it occurs. The editorial went further to assert that “it is clear that timely defibrillation in the hospital is an important determinant of the quality of cardiovascular care.”²²

The current analysis failed to confirm a relationship between delayed defibrillation and survival for patients arresting in the operating room. We speculate several potential reasons why delayed defibrillation may not be associated with survival for cardiac arrest occurring in the operating room. Baseline characteristics of patients may differ in the operating room compared with other locations. For example, patients who arrested in the operating room were less likely to have a preexisting diagnosis of myocardial infarction, a diagnosis shown to predict sensitivity to delayed defibrillation in multivariate analysis of our population (table 4). Conversely, hemorrhage was more commonly identified in the operating room, a diagnosis that did not predict sensitivity to delayed defibrillation in multivariable analysis (table 5). In fact, patients with hemorrhage demonstrated a trend toward improved survival with delay in defibrillation. Hemorrhage may be lethal regardless of rhythm. In the hemorrhaging patient, an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia may rapidly deteriorate to asystole or

Table 4. Association between Delayed Defibrillation and Survival by MI This Admission (n = 777)*

Variable	Survived Event				Survived to Discharge			
	MI This Admission n/N = 177/234 (75.6%)		No MI This Admission n/N = 372/543 (68.5%)		MI This Admission n/N = 131/234 (56.0%)		No MI This Admission n/N = 264/543 (48.6%)	
	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value
Delayed defibrillation† (n = 110)	0.19 (0.07, 0.52)	0.001	0.74 (0.45, 1.22)	0.241	0.16 (0.05, 0.59)	0.005	0.90 (0.56, 1.46)	0.677
Age	0.97 (0.95, 1.00)	0.040	0.99 (0.98, 1.00)	0.235	0.96 (0.94, 0.98)	<0.001	0.98 (0.97, 1.00)	0.005
Male sex (n = 505)	0.92 (0.46, 1.86)	0.827	0.64 (0.43, 0.95)	0.029	1.34 (0.73, 2.48)	0.344	0.94 (0.65, 1.35)	0.724
White race‡ (n = 606)	0.98 (0.43, 2.23)	0.968	1.30 (0.84, 2.00)	0.243	0.79 (0.37, 1.66)	0.535	1.30 (0.86, 1.98)	0.219
Cardiac patient (medical or surgical)§ (n = 382)	0.93 (0.39, 2.22)	0.877	1.86 (1.19, 2.90)	0.006	1.10 (0.49, 2.49)	0.819	2.18 (1.46, 3.25)	<0.001
Weekday or evening arrest (n = 612)	0.86 (0.41, 1.82)	0.702	1.75 (1.12, 2.75)	0.014	0.86 (0.45, 1.64)	0.650	2.15 (1.35, 3.40)	0.001
Ventricular fibrillation (n = 558)	1.52 (0.76, 3.06)	0.237	0.75 (0.49, 1.14)	0.181	1.98 (1.03, 3.79)	0.040	0.90 (0.61, 1.33)	0.610
Operating room (n = 340)	0.55 (0.26, 1.18)	0.124	0.84 (0.56, 1.26)	0.405	0.55 (0.26, 1.14)	0.108	0.75 (0.51, 1.10)	0.138

* The variable designating a myocardial infarction (MI) this admission was missing for 88 cases. † Delayed defibrillation is more than 2 min from the time of pulselessness until the time of defibrillation. ‡ Race was determined by the hospital investigators. White race was compared with all others, including American Indian/Eskimo/Aleutian, Asian/Pacific Islander, Black, Other, Unknown. § Cardiac medical or surgical patients were compared with patients classified as noncardiac medical or surgical, trauma, or obstetric. || Weekday or evening arrests took place between 7:00 AM and 11:00 PM Monday through Friday.

CI = confidence interval.

pulseless electrical activity, rhythms that would be unresponsive to defibrillation and would carry a worse prognosis. A focus on advanced cardiac life support and rapid defibrillation may conflict with optimal management of surgical hemorrhage if the effort inhibits surgical access to the operative site.^{23,24} More broadly, with intraoperative arrest, if providers are engaged in activity that is expected to reverse the etiology of the arrest, they may defer defibrillation to focus on performing the critical actions as rapidly and reliably as possible.

Alternatively, unique processes of care may explain the lack of relationship between defibrillation and survival in the operating room. For example, some intraoperative patients may be treated with cardiopulmonary bypass before defibrillation. In addition, the operating room is the only location where a resuscitation expert with no surgical or procedural responsibilities (*i.e.*, the anesthesia provider) is guaranteed to be at the patient's bedside. Therefore, in the operating room, delays in defibrillation may be less likely to signal other quality gaps in patient care. Finally, our inability to detect an association between delayed defibrillation and survival for patients arresting in the operating room may have been due to an inadequate sample size of intraoperative arrests.

In many locations of the hospital, including periprocedural areas, prompt defibrillation can improve outcomes for patients presenting with ventricular fibrillation or pulseless ventricular tachycardia. The relationship is sufficiently robust that defibrillation within 2 min may be considered a useful process measure to indicate high-quality resuscitation care. This relationship was not confirmed in the operating room. We suggest that a very large database of intraoperative cardiopulmonary arrest is needed to evaluate the relative contributions of surgical variables and process variables on survival outcomes.

Strengths

This analysis focused on patients with cardiac arrest caused by ventricular fibrillation or pulseless ventricular tachycardia and excluded other potentially inappropriate patients, such as those with preexisting implantable cardioverter-defibrillators. Drawing data from more than 250 hospitals, the large size of NRCPR, and its use of standardized definitions, suggests a representative sample of relatively reliable data.

Limitations

Limitations of the NRCPR dataset include: (1) registry hospitals may not be representative of all US hospitals; (2) the

Table 5. Association between Delayed Defibrillation and Survival by Preexisting Hemorrhage (n = 789)*

Variable	Survived Event				Survived to Discharge			
	Hemorrhage n/N = 75/136 (55.2%)		No Hemorrhage n/N = 477/653 (73.1%)		Hemorrhage n/N = 37/136 (27.2%)		No Hemorrhage N = 359/653 (55.0%)	
	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value	Adjusted Odds Ratio (95% CI)	P Value
Delayed defibrillation† (n = 112)	1.23 (0.42, 3.6)	0.708	0.49 (0.31, 0.79)	0.003	2.43 (0.86, 6.86)	0.094	0.58 (0.37, 0.92)	0.020
Age	1.02 (0.99, 1.04)	0.145	0.98 (0.97, 0.99)	0.004	0.99 (0.97, 1.02)	0.511	0.98 (0.97, 0.99)	<0.001
Male sex (n = 514)	0.34 (0.15, 0.76)	0.009	0.77 (0.53, 1.12)	0.170	0.51 (0.22, 1.18)	0.116	1.08 (0.77, 1.50)	0.653
White race‡ (n = 613)	0.50 (0.20, 1.25)	0.140	1.46 (0.96, 2.22)	0.075	0.69 (0.27, 1.75)	0.437	1.32 (0.90, 1.95)	0.158
Cardiac patient (medical or surgical)§ (n = 384)	1.33 (0.54, 3.26)	0.539	1.44 (0.97, 2.12)	0.070	1.60 (0.63, 4.08)	0.322	1.56 (1.09, 2.22)	0.014
Weekday or evening arrest (n = 620)	1.05 (0.46, 2.38)	0.906	1.43 (0.93, 2.18)	0.102	1.27 (0.49, 3.30)	0.622	1.48 (1.01, 2.19)	0.047
Ventricular fibrillation (n = 568)	0.71 (0.32, 1.61)	0.415	0.91 (0.61, 1.35)	0.637	0.94 (0.38, 2.30)	0.885	1.10 (0.77, 1.57)	0.609
Operating room (n = 348)	0.97 (0.41, 2.32)	0.945	0.80 (0.55, 1.19)	0.274	0.66 (0.26, 1.67)	0.383	0.85 (0.60, 1.22)	0.386

* The variable designating hemorrhage was missing for 77 cases. † Delayed defibrillation is more than 2 min from the time of pulselessness until the time of defibrillation. ‡ Race was determined by the hospital investigators. White race was compared with all others, including American Indian/Eskimo/Aleutian, Asian/Pacific Islander, Black, Other, Unknown. § Cardiac medical or surgical patients were compared with patients classified as noncardiac medical or surgical, trauma, or obstetric. || Weekday or evening arrests took place between 7:00 AM and 11:00 PM Monday through Friday.

CI = confidence interval.

accuracy of documented times may be problematic, particularly in the diagnostic suite where 25% of patients were not monitored at the time of their arrest; and (3) potentially important data elements were not available (*e.g.*, American Society of Anesthesiologists' functional status and emergency designation, the diagnosis of hemorrhage, the estimated blood loss, and the type of operative or nonoperative procedure). The variable used to designate hemorrhage in this analysis was a composite variable that may not accurately represent true hemorrhage. The variables designating cause of arrest were abstracted from the medical record by NRCPR research coordinators not involved in clinical care of the patient, and the accuracy of these recorded causes has not been validated. Because the registry only captures events that elicit a hospital response or require use of a crash cart, "arrests" in the cardiac catheterization laboratory and the cardiac operating room may be treated per routine and may not have been reported in the NRCPR.

Results may have differed for the 91 patients excluded because the time to defibrillation was missing. The patients excluded for missing time information were more likely to arrest in the operating room, and this subgroup likely includes a mixed population of relatively young trauma pa-

tients for whom prognosis was poor regardless of defibrillation times as well as cardiac surgical patients for whom other interventions (cardiopulmonary bypass) dictated survival. A total of 41 patients arrested because of conscious sedation, and of these 8 were missing information on time to defibrillation. Although this rate was significantly increased, the numbers are relatively small, and this finding needs to be confirmed in future analyses.

Finally, a relatively large number of analyses were conducted when compared with the number of actual events observed. Therefore, the associations presented in this paper need to be verified in future populations of patients with cardiopulmonary arrest.

This is the first paper to use the American Heart Association NRCPR to explore the effect of a process measure (delayed defibrillation) on survival in the perioperative environment. The current analysis suggests that this database may be improved for addressing questions about perioperative care by including procedural-specific variables such as the operative or nonoperative procedure, the primary anesthetic technique, the estimated blood loss before arrest, and the American Society of Anesthesiology physical examina-

tion status. Alternatively, questions of perioperative and periprocedural resuscitation quality may best be addressed by linking the NRCPR with more detailed databases of perioperative and periprocedural care.²⁵

Conclusion

Delays in defibrillation follow 13.8% of in-hospital intraoperative and periprocedural cardiac arrests, despite the presence of numerous medical and nursing personnel. These delays were associated with lower hospital survival for patients with periprocedural, but not intraoperative, cardiac arrests. More research is needed to define and explain the relationship between time to defibrillation and survival for intraoperative cardiac arrests.

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Appendix 1: The American Heart Association National Registry of CPR Investigators

The American Heart Association National Registry of CPR investigators includes: Paul S. Chan, M.D., M.Sc., Assistant Professor of

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Appendix 2. Comparison of Included Cases and Those Excluded for Missing Time Data

Characteristic	Included (n = 865)	Missing Time (n = 91)	P Value
Age, year (mean \pm SD)	63.8 \pm 15.8	59.2 \pm 17.7	0.009
Male sex, No. (%)	566 (65.4)	57 (62.6)	0.59
White race*, No. (%)	675 (78.0)	69 (75.8)	0.63
Pulseless ventricular tachycardia†, No. (%)	245 (28.3)	28 (30.8)	0.62
Event location, No. (%)			
Operating room or same-day surgery center	373 (43.1)	71 (78.0)	<0.001
Perianesthesia care unit	145 (16.8)	2 (2.2)	
Cardiac catheterization laboratory	264 (30.5)	15 (16.5)	
Diagnostic suite	83 (9.6)	3 (3.3)	
Illness category, No. (%)			<0.001
Medical, cardiac	304 (35.1)	18 (19.8)	
Medical, noncardiac	76 (8.8)	7 (7.7)	
Surgical, cardiac	133 (15.4)	25 (27.5)	
Surgical, noncardiac	321 (37.1)	30 (33.0)	
Other (trauma or obstetric)	31 (3.6)	11 (12.1)	
Preexisting conditions, No. (%)			
Data on preexisting conditions not collected	88 (10.2)	11 (12.1)	0.57
Congestive heart failure at admission	83 (10.7)	7 (8.8)	0.59
Previous congestive heart failure	126 (16.2)	11 (13.8)	0.57
Myocardial infarction at admission	234 (30.1)	22 (27.5)	0.63
Previous myocardial infarction	159 (20.5)	18 (22.5)	0.67
Respiratory insufficiency	206 (26.5)	29 (36.3)	0.06
Renal insufficiency	151 (19.4)	11 (13.8)	0.22
Hepatic insufficiency	13 (1.7)	2 (2.7)	0.19
Metabolic or electrolyte derangement	82 (10.6)	8 (10.0)	0.88
Diabetes mellitus	195 (25.1)	14 (17.5)	0.13
Baseline central nervous system deficit	63 (8.1)	7 (8.8)	0.84
Acute stroke	16 (2.1)	1 (1.3)	0.62
Acute nonstroke neurologic disorder	34 (4.4)	6 (7.5)	0.21
Pneumonia	19 (2.5)	2 (2.5)	0.98
Sepsis	43 (5.5)	4 (5.0)	0.84
Hemorrhage‡	136 (17.2)	23 (27.4)	0.02
Major trauma	41 (5.3)	11 (13.8)	0.003
Cancer	54 (7.0)	4 (5.0)	0.51

(continued)

Appendix 2. Continued

Characteristic	Included (n = 865)	Missing Time (n = 91)	P Value
Immediate cause of arrest, No. (%)			
Immediate cause of arrest not collected	41 (4.7)	6 (6.6)	0.44
Active myocardial ischemia or evolving myocardial infarction	135 (16.4)	17 (20.0)	0.40
Acute pneumothorax	4 (0.5)	0	0.52
Acute pulmonary edema	8 (1.0)	0	0.36
Acute pulmonary embolism	9 (1.1)	1 (1.2)	0.94
Acute respiratory insufficiency	132 (16.0)	16 (18.8)	0.51
Acute stroke	2 (0.2)	0	0.65
Arrhythmia (excluding sinus tachycardia)	659 (80.0)	55 (64.7)	0.001
Conscious/procedural sedation	33 (4.0)	8 (9.4)	0.02
Hypotension/hypoperfusion	281 (34.1)	38 (44.7)	0.05
Hypothermia	2 (0.2)	1 (1.2)	0.15
Inadequate or obstruction of invasive airway	5 (0.6)	0	0.47
Inadequate or obstruction of natural airway	15 (1.8)	0	0.21
Status epilepticus	2 (0.2)	0	0.65
Metabolic or electrolyte abnormality	47 (5.7)	5 (5.9)	0.95
Adverse drug effect or reaction	6 (0.7)	0	0.43
Infusions in place at the time of arrest, No. (%)			
Data on continuous infusions not collected, No. (%)	48 (5.6)	6 (6.6)	0.68
Epinephrine	49 (6.0)	11 (12.1)	0.01
Lidocaine	23 (2.8)	4 (4.4)	0.33
Amiodarone	39 (4.8)	4 (4.4)	0.98
Monitoring in place at the time of arrest, No. (%)			
Operating room	358 (96.0)	67 (94.4)	0.54
Perianesthesia care unit	137 (94.5)	2 (100.0)	0.73
Cardiac catheterization laboratory	263 (99.6)	15 (100.0)	0.81
Diagnostic suites	62 (74.7)	2 (66.7)	0.75
Length of stay less than 1 day	159 (18.4)	28 (30.8)	0.005
Survived event, No. (%)	612 (70.8)	49 (53.9)	0.001
Survived to discharge, No. (%)	443 (51.2)	30 (33.0)	0.001

* Race was determined by the hospital investigators. White race was compared with all others, including American Indian/Eskimo/Aleutian, Asian/Pacific Islander, Black, Other, Unknown. † Pulseless ventricular tachycardia was compared with ventricular fibrillation. ‡ Hemorrhage defined if the patient received any blood product transfusion or aortic cross-clamping, or had preexisting hypotension or hypoperfusion without an acute nonstroke event, acute stroke, sepsis, pneumonia, myocardial infarction, or congestive heart failure in the current admission.

Appendix 3. Independent Predictors of Missing Time to Defibrillation (n = 91 of 956)

Variable	Adjusted Odds Ratio (95% CI)	P Value
Operating room event location	8.18 (2.06, 32.42)	0.003
Immediate cause of arrest		
Conscious sedation	4.22 (1.74, 10.22)	0.001
Arrhythmia (excluding sinus tachycardia)	0.46 (0.27, 0.77)	0.004

Controlling for patient age, sex, race, presenting rhythm, illness category, location of arrest, preexisting trauma or hemorrhage, and brief length of stay.

CI = confidence interval.