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FAMILY PRESENCE DURING RESUSCITATION AND PATTERNS OF CARE DURING IN-HOSPITAL CARDIAC ARREST

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Abstract

Background—A growing number of hospitals have begun to implement policies allowing for family presence during resuscitation (FPDR); the safety of these policies and their affect on patterns of care is unknown.

Objective—To measure the association between FPDR and processes and outcomes of care following in-hospital cardiac arrest.

Design—Observational cohort study.

Setting—Get With the Guidelines—Resuscitation (GWTG–R) a large, multicenter observational registry capturing in-hospital cardiac arrests.

Participants—41,568 adult patients at 252 hospitals in the United States.

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Measurements—The exposure was a hospital-level policy to allow FPDR. Primary outcomes included return of spontaneous circulation (ROSC) and survival to discharge. Secondary outcomes included the quality, interventions, and self-reported potential systems errors associated with resuscitation.

Results—There were no significant differences in ROSC or survival to discharge in hospitals with and without a FPDR policy in unadjusted or adjusted analyses. There was a small, borderline significant decrease in the mean time to defibrillation at hospitals with a FPDR policy compared to hospitals without a FPDR policy during adjusted analysis ($p=0.05$). Similarly, there was a significant increase in the risk-adjusted median duration of resuscitation among non-survivors in hospitals with FPDR ($P=0.04$). Other resuscitation quality, pharmacologic and non-pharmacologic interventions, and potential self-reported systems-level resuscitation errors did not meaningfully differ between hospitals with and without a FPDR policy.

Limitation—GWTG-R may not be representative of all hospitals. Furthermore, it does not collect information on whether families were actually present during the arrests recorded.

Conclusion—Hospitals with a policy allowing families to be present during resuscitation generally have similar outcome and processes of care as hospitals without a FPDR policy suggesting such policies do not negatively impact resuscitation outcomes and processes. Expanding hospital implementation policies allowing FPDR may offer substantial opportunity for enhancing the practice of resuscitation care.

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BACKGROUND

The attempted resuscitation of a hospitalized patient is an emotionally charged event where a family must confront the possibility of a loved one's death. In the hope of addressing the emotional needs of family members during resuscitation, many institutions have adopted policies that allow for family presence during resuscitation (FPDR). Recent evidence suggests that FPDR confers psychological benefits for family members present during arrests in both the out-of-hospital (1) and in-hospital setting,(2) regardless of the treatment outcome. Furthermore, patients are proponents of having relatives at the bedside during resuscitation as well.(3, 4) As a result, a growing number of hospitals have begun to implement policies allowing for FPDR(5) with some demonstrating improvements in family member satisfaction surrounding the resuscitation event.(6)

However, there remains uncertainty surrounding the use of such policies during resuscitation.(7) Many hospitals remain reluctant to allow FPDR, given concerns that such policies may impact the quality and, ultimately, outcome of resuscitation.(8) Some experts speculate that, FPDR could directly and indirectly have a negative influence on the way in which providers perform attempted resuscitation.(9-12) Reasons cited include the perception that families might interrupt care, the lack of space to accommodate family members in the room, and a perceived increased risk of litigation.(13, 14) Conversely, FPDR may have little impact on the process and outcome of care, which would be important to document given their psychological benefits for family members.

Given the increasing importance of patient-centered care, universal implementation of FPDR policies is a compelling means to change the paradigm of resuscitation care. However, greater empirical evidence on its impact on patterns of care is needed to ensure its safety given the potential for unintended consequences. To address this uncertainty, we analyzed a large cohort of patients participating in the largest national registry of in-hospital cardiac arrest at hospitals with and without a FPDR policy. We hypothesized that hospitals with a FPDR policy would have similar processes and outcomes of care following in-hospital cardiac arrest compared to those without such a policy.

METHODS

Data Source

Formerly known as the National Registry of Cardiopulmonary Resuscitation (NRCPR), the Get With the Guidelines–Resuscitation (GWTG–R) is a large, multicenter observational registry capturing in-hospital cardiac arrests at approximately 600 hospitals across the United States.⁽¹⁵⁾ Details of the database have been previously described.⁽¹⁶⁾ Briefly, trained research personnel at participating hospitals prospectively collect information on consecutive patients with in-hospital cardiac arrests, defined by the absence of a central palpable pulse, apnea, and unresponsiveness. Cases are identified by centralized collection of one or more of cardiac arrest flow sheets, reviews of hospital paging-system logs, routine checks for use of emergency equipment, and hospital billing charges for resuscitation medications. The registry uses precisely defined variables for uniform reporting of cardiac arrests developed by international experts (Utstein definitions).⁽¹⁷⁾ Oversight for the entire process of data collection, analysis, and reporting is provided by the American Heart Association (AHA), its National Center staff, the NRCPR/GWTG–R Scientific Advisory Board, and the AHA Executive Database Steering Committee.

Exposure Definition

In 2006, GWTG–R introduced a variable on their data collection form, asking whether hospitals participating in the registry whether they have a policy allowing for FDPR, defined as “policy allowing for family presence during adult events.” This reflects a policy decision at the hospital level, but importantly does not capture whether a family member was present during the arrest for a given patient. This variable was collected at 3 points in time—on the 2006, 2008, and 2009 data collection forms.

Study Population

Because data on the policy for FPDR was not collected prior to 2007, we focused our analysis on patients aged 18 years or older with (1) arrests occurring between January 1, 2007 and September 24, 2010; (2) complete clinical and demographic data, and (3) admitted to hospitals with complete data on whether they documented a policy allowing for FPDR (n=50,624). We limited our sample to 44,538 patients with an index arrest (i.e., the first arrest for a patient during a hospitalization) due to pulseless ventricular tachycardia (VT), ventricular fibrillation (VF), pulseless electrical activity (PEA), or asystole. We excluded 2,770 patients who experienced their arrest in procedure areas (delivery, cardiac catheterization, electrophysiology, and angiography suites), or whose location was unknown

or missing at the time of their cardiac arrest. We excluded these patients because families have less opportunity to be present during cardiac arrests in such settings. We also excluded 200 patients with implantable cardioverterdefibrillators who had a VT/VF arrest, given that their arrest would likely be rapidly terminated by the implanted device and the outcomes of such arrest are independent of the code-team efforts. Our final study sample consisted of 41,568 patients at 252 hospitals (Figure 1).

Study Outcomes

We evaluated primary and secondary outcomes aimed at characterizing the outcomes of resuscitation. Our primary outcomes included: a) return of spontaneous circulation (ROSC), defined as the restoration of a pulse for at least 20 minutes during the cardiac arrest, and b) survival to discharge. To address concerns about whether any observed changes in survival associated with the FPDR policy may result in worse neurologic status at the time of discharge, we also evaluated neurologic outcomes among survivors by FDPR. Information on neurological status was obtained using cerebral performance categories (CPCs): no major disability, moderate disability, severe disability, coma or vegetative state, and brain death. (18) Consistent with prior work, we categorized favorable neurological status among those surviving to hospital discharge as a CPC score of 1 or 2.(19)

To assess the direct impact of the presence or absence of a hospital FPDR policy on the process and quality of care, we examined three broad categories of secondary outcomes. These included a) the quality of the resuscitation, b) the aggressiveness of the resuscitation, and c) self-reported potential systems errors that occurred during resuscitation. To measure the quality of resuscitation we examined three measures shown to correlate with improved survival after resuscitation: time to defibrillation;(20) receipt of chest compressions;(21, 22) and the duration of attempted resuscitation in non-survivors defined at the hospital level.(23)

We also evaluated the aggressiveness of the resuscitation by determining the percentage of patients who received any one of several intra-arrest pharmacologic interventions in aggregate (amiodarone, lidocaine, dobutamine, dopamine, norepinephrine, phenylephrine, atropine, calcium chloride, IV fluid bolus, magnesium sulfate, sodium bicarbonate), as well as each intervention separately. We also examined the percentage of patients who received any of several non-pharmacologic therapies in aggregate (invasive airway, blood transfusion, central venous catheter, chest tube, echocardiogram, transcutaneous pacemaker, transvenous pacemaker, pericardiocentesis), as well as each intervention separately. We recognized the fact that many patients may not have undergone a resuscitative effort long enough to receive certain interventions (particularly patients who achieved ROSC early). Therefore, as a sensitivity analysis, we examined interventions given to non-survivors, where the duration of resuscitation may have been extended before stopping the resuscitation (Appendix Table 2). We also examined the median number of shocks delivered to non-survivors for those arrests with a first recorded rhythm of VT/VF.

Finally, we determined the frequency of several potential reported systems errors during resuscitation, both in aggregate as well as separately. Based on previous work,(24) these included potential errors related to alerting of the arrest, airway deployment, vascular access,

chest compression quality, defibrillation, medications, code team leadership, Advanced Cardiac Life Support guidelines, and equipment.

Statistical Analyses

For baseline comparisons, we evaluated patient and hospital characteristics across hospitals by FPDR status using bivariate regression models that accounted for clustering of patients' outcomes within hospitals using generalized estimation equations with a robust variance estimates.⁽²⁵⁾ Continuous variables were compared using linear regression while categorical comparisons employed logistic regression. To determine the association between FPDR and patients achieving ROSC, survival to discharge, and a favorable neurologic status at discharge, we used multilevel Poisson regression models with hospital-specific, random intercepts because of the skewed distribution of these variables.⁽²⁶⁾

For both our primary and secondary outcomes, we adjusted for several patient- and hospital-level covariates that potentially confound the relationship between FPDR status and each outcome based upon previous work (Appendix Table 4).⁽²⁷⁾ Results were presented as both unadjusted and adjusted analyses to demonstrate the impact of adjustment on the associations.

We used Stata version 12.1 (StataCorp, LP, College Station, TX) for all analyses and considered 2-sided p-values of <0.05 as significant. The Institutional Review Board of the University of Washington reviewed the study protocol and determined that it was not considered Human Subjects Research.

RESULTS

Baseline Characteristics

After applying exclusions, our sample consisted of 41,568 patients at 252 hospitals (Figure 1). Of these, 13,470 patients were at 80 hospitals with a policy allowing for FPDR. There were significant differences in the adoption of a FPDR policy by geographic region ($p=0.002$) (Table 1). Specifically, hospitals located in the North Central and Mountain/Pacific regions were more likely to have a FPDR policy, while hospitals located in the South Atlantic were less likely (Table 1). There were no significant differences in patient characteristics across hospitals with versus without a FPDR policy, including age, race, gender, location of the arrest, or pre-existing comorbidities (Table 2).

Primary Outcomes

Overall, 57.6% ($n=23,942$) patients achieved ROSC and 17.6% ($n=7,301$) survived to discharge. In unadjusted analyses, we observed a significant difference in hospital rates of ROSC (58.1% vs. 55.8%, $p=0.045$) for hospitals with vs. without a FPDR policy, respectively (Table 3a). However, these differences favoring hospitals with a FPDR did not persist upon adjustment for patient and hospital characteristics (Table 3b). There were no significant differences in survival to discharge or survival to discharge with a favorable neurologic status by FPDR policy in unadjusted or adjusted analyses (Table 3a, 3b). Finally, while patients with PEA/asystole had a significantly higher rate of ROSC in FPDR hospitals

(55.4% vs. 52.6, $p=0.03$), and a trend toward significance in survival to discharge (14.1% vs 12.6, $p=0.07$), there were no differences in survival rates for shockable (VT/VF) or unshockable (asystole/PEA) cardiac arrest rhythms after multivariable adjustment.

Secondary Outcomes

Resuscitation Quality—Parameters assessing the quality of resuscitation are shown in Table 4. We noted no significant difference in the proportion of patients receiving chest compressions between hospitals with and without FPDR (Table 4). However, there was a small difference in the mean time to defibrillation, with slightly faster times in hospitals with a policy for FPDR (2.1 vs. 2.4 minutes; $p=0.03$) that remained significant on adjusted analysis ($p=0.05$). Similarly, there was a significant increase in the adjusted median duration of resuscitation among non-survivors in hospitals with FPDR (mean difference -1.4 minutes, 95% CI -2.7 to -0.08 , $p=0.04$). Finally, there were no significant differences in the median number of shocks delivered or the percent of patients receiving compressions.

Resuscitation Interventions—Aggressiveness of the resuscitation event was similar across hospitals differing in FPDR status. There were no significant differences among the broad categories of pharmacologic and non-pharmacologic interventions delivered during the arrest between hospitals with and without a policy allowing for FPDR, in both unadjusted and adjusted analyses (Table 4).

Upon examination of each individual pharmacologic interventions, administration of norepinephrine was greater at hospitals with FPDR (OR 1.57, 95% CI 1.18-2.08) and atropine was lower at hospitals with FPDR policies (OR 0.88, 95% CI 0.78-0.99) in adjusted analysis. Among non-pharmacologic interventions, there were no differences by FPDR status in adjusted analysis (Appendix Table 1), and only norepinephrine represented significant difference in adjusted analyses, looking specifically at interventions given to non-survivors (Appendix Table 2).

Potential Systems Resuscitation Errors—When measuring broad categories of self-reported potential systems errors in resuscitation, adjusted analysis suggested that the policy for FPDR was significantly associated with more potential errors pertaining to vascular access. Analysis of individual errors suggested that resuscitations in FPDR hospitals more often had greater delays in vascular access (OR 1.87, [95% CI 1.15-3.03]), more often experienced IV infiltration or disconnection (OR 1.74, [95% CI 1.10-2.74]), and had the wrong medication selected (OR 2.56, [95% CI 1.0-6.5]) (Appendix Table 3).

DISCUSSION

Utilizing data on in-hospital arrest from over 200 hospitals in the United States, we determined that hospitals with a policy allowing families to be present during resuscitation had similar rates of ROSC and survival to discharge as hospitals without a FPDR policy. Equivalence in outcomes across hospitals was also reflected by the similar characteristics of the arrests and the resuscitation efforts within hospitals differing by FPDR policy. Specifically, the resuscitation quality, pharmacologic and non-pharmacologic interventions, and potential self-reported systems-level resuscitation errors did not meaningfully differ

between hospitals with and without a FPDR policy. To our knowledge, this is the first large study to determine that a hospital policy allowing for FPDR did not negatively affect the outcomes and quality of in-hospital resuscitative efforts.

Since its first description in the medical literature nearly three decades ago,(28) FPDR has generated considerable debate, and remains a contentious issue worldwide.(29) Support for FPDR is largely based on qualitative and survey investigations that demonstrated a beneficial impact of FPDR on psychological outcomes for families.(2, 6, 28, 30) In response to favorable outcomes among family members witnessing resuscitation, numerous professional guidelines now endorse policies that allow for FPDR.(2, 8, 17, 31) Despite these guidelines, a large proportion of healthcare professionals still oppose it, often citing concerns that families may disrupt the resuscitation efforts in adverse ways.(32, 33) However, there is a paucity of empirical evidence demonstrating that FPDR negatively affects resuscitation practice.

Prior studies that explicitly examined the association between FPDR and outcomes have been mixed. In an analysis of simulated resuscitations in an urban emergency department, Fernandez and colleagues demonstrated that FPDR may have a significant impact on physicians' ability to perform critical interventions as well as resuscitation-based performance outcomes.(14) The presence of a witness was associated with longer times to defibrillation (mean of 2.6 vs. 1.7 minutes) and fewer shocks (median number of 4.0 vs. 6.0). In a separate cluster-randomized trial, investigators in France prospectively evaluated 570 family members present at their relatives' arrests occurring at home.(1) Family members who were randomized to a policy of being explicitly offered the opportunity to observe the arrests (the intervention), as well as those who actually witnessed the arrest, had a significantly lower incidence of self-reported post-traumatic stress-related symptoms 3 months after the resuscitation. Importantly, FPDR did not significantly impact medical personnel efforts or the resuscitation outcomes, including survival, drugs administered, duration of resuscitation, and shocks delivered, although the sample size may have precluded identification of small but important differences.

In our study, the exposure of interest was the presence of a hospital policy allowing FPDR rather than actual FPDR. Therefore, our findings are most relevant to hospitals considering developing (or rescinding) a policy for FPDR. In contrast to the simulation study by Fernandez, we found no differences in the median number of shocks across FPDR status. Furthermore, we demonstrated a statistically significant, shorter mean time to defibrillation in hospitals where families were allowed to be present (2.1 vs. 2.4 minutes), although the clinical significance of such a small difference is not clear. In the absence of a pattern of significant differences in other important outcomes across a policy of FPDR and given the large number of comparisons, this finding may be spurious in nature. Our results also parallel the nonsignificant differences in secondary outcomes shown from inpatient follow-up from out-of-hospital resuscitations in France.(1)

Our finding that a policy for family presence may have no impact on resuscitation practice may be viewed by some as surprising. In-hospital cardiac arrests differ from arrests that occur in the out-of-hospital setting in several important ways. In-hospital arrests often rely

on the coordinated efforts of several providers, including physicians, nurses, pharmacists and trainees, and often occur in space-constrained environments such as the typical hospital room. These factors likely increase the impact of FPDR on the resuscitation effort. For example, if family presence directly or indirectly increases stress or disrupts communication or coordination of efforts among providers during the resuscitative attempt, providers may be more likely to commit errors during resuscitation. Moreover, providers may be compelled to deliver more aggressive and potentially unwanted care in the presence of family members, or, alternatively, may cease efforts more quickly when family members change the goals of care while witnessing the resuscitation. Although such mechanisms may impact individual resuscitations, our data suggest that these mechanisms do not impact aggregate resuscitation efforts or outcome at the hospital level.

Our study should be interpreted in the context of several limitations. First, while GWTG–R offers a unique opportunity to study the hospital policy allowing for FPDR, it is a voluntary registry that may not be representative of all hospitals. Nevertheless, registry data provides the best real-world insights into the processes and outcomes of resuscitation in current clinical practice,⁽¹⁵⁾ and provides the only practical way to examine rare events such as errors in resuscitation. Second, the limited number of FPDR hospitals may have lowered our power to detect a significant difference. However, the GWTG–R affords the largest registry of FPDR data available in the United States, arguing that the effect we see here would be consistent across other registries or hospital data. Third, we recognize that many providers may interpret and facilitate the policy for FPDR in different ways. This variation in practice may affect the degree to which a hospital integrates families into the resuscitation itself. Indeed, they may often be silent “bystanders,” conferring no direct impact on the actual mechanics of the resuscitation

Fourth, as with any observational registry there remains the possibility that errors may occur during data collection. Specifically, there may be variation in how reliably hospitals document the presence of a policy or not, and the self-reporting of potential errors. Finally, while the GWTG–R is able to capture the hospital policy allowing for FPDR, it does not collect information on whether families were actually present during the arrests recorded. As a consequence, we are unable to directly measure the impact of a family at the bedside on an individual resuscitation itself. This makes our study susceptible to the ecological fallacy,⁽³⁴⁾ and our data should not be interpreted to mean that a lack of a correlation at the hospital-level would hold true for individual patients. Nonetheless, our study supports previous literature suggesting little appreciable harm on resuscitation outcomes attributable to FPDR. Future studies examining the impact of FPDR on patient outcomes should collect the actual presence of family members during resuscitation.

In spite of these limitations, we believe our results suggest that expanding hospital implementation policies allowing FPDR offers a substantial opportunity for changing the paradigm of resuscitation and may be done safely. Guideline developers now have a more robust foundation of evidence refuting harms of FPDR upon which they can base a recommendation that hospitals adopt FPDR policies. Future studies are needed to extend our understanding of in-hospital FPDR by investigating its impact on individual resuscitations,

barriers to implementation of these policies, and possibly refining our ways of measuring its impact on families.

Appendix

Appendix Table 1

Specific interventions delivered at hospitals with and without a policy for FPDR

	Unadjusted analysis				Adjusted analysis	
	All patients (n=41,568) 252 hospitals	Patients at hospital with a policy for FPDR (n=13,470) 80 hospitals	Patients at hospital without a policy for FPDR (n=28,098) 172 hospitals	P-value [*]	OR ^{**} (95% CI)	P-value
Non-pharmacologic interventions, n (%)						
Invasive airway	17,577 (42.3)	5,659 (42.0)	11,918 (42.4)	0.69	1.00 (0.88-1.15)	0.94
Blood transfusion	1,675 (4.0)	589 (4.4)	1,086 (3.9)	0.05	1.08 (0.89-1.30)	0.43
Central venous catheter	4,126 (9.9)	1,521 (11.3)	2,605 (9.3)	0.46	0.96 (0.62-1.50)	0.86
Chest thoracostomy tube	510 (1.2)	200 (1.5)	310 (1.1)	0.04	1.27 (0.95-1.70)	0.11
Echocardiogram	867 (2.1)	300 (2.2)	567 (2.0)	0.33	0.94 (0.63-1.39)	0.76
Transcutaneous pacemaker	1,850 (4.5)	603 (4.5)	1,247 (4.4)	0.84	1.03 (0.83-1.29)	0.77
Transvenous pacemaker	884 (2.1)	251 (1.9)	633 (2.3)	0.16	0.83 (0.64-1.08)	0.17
Pericardiocentesis	339 (0.8)	117 (0.9)	222 (0.8)	0.43	1.01 (0.71-1.43)	0.94
Pharmacologic interventions, n (%)						
Amiodarone	7,566 (18.2)	2,544 (18.9)	5,022 (17.9)	0.31	1.06 (0.94-1.20)	0.30
Lidocaine	2,778 (6.7)	871 (6.5)	1,907 (6.8)	0.59	1.05 (0.89-1.22)	0.58
Dobutamine	1,625 (3.9)	588 (4.4)	1,037 (3.7)	0.33	1.06 (0.81-1.39)	0.66
Dopamine	9,019 (21.7)	2,964 (22.0)	6,055 (21.6)	0.74	1.06 (0.88-1.27)	0.53
Norepinephrine	9,130 (22.0)	3,483 (25.9)	5,647 (20.1)	0.03	1.57 (1.18-2.08)	0.002
Phenylephrine	3,318 (8.0)	975 (7.2)	2,343 (8.3)	0.95	0.81 (0.53-1.23)	0.32
Atropine	30,043 (72.3)	9,615 (71.4)	20,428 (72.7)	0.01	0.88 (0.78-0.99)	0.04
Calcium chloride	11,888 (28.6)	4,041 (30.0)	7,847 (27.9)	0.16	1.02 (0.89-1.18)	0.74
IV fluid bolus	13,285 (32.0)	4,406 (32.7)	8,879 (31.6)	0.61	0.87 (0.67-1.13)	0.30
Magnesium sulfate	4,112 (9.9)	1,459 (10.8)	2,653 (9.4)	0.49	0.92 (0.78-1.09)	0.33
Sodium bicarbonate	22,409 (53.9)	7,142 (53.0)	15,266 (54.3)	0.44	0.93 (0.83-1.03)	0.17

* P-values derived from bivariate generalized linear models. These models accounted for clustering of patients within hospitals.

** Odd-ratios adjusted for patient and hospital characteristics

Appendix Table 2

Specific interventions delivered to non-survivors at hospitals with and without a policy for FPDR

	Unadjusted analysis				Adjusted analysis	
	All patients (n=17,626) 247 hospitals	Patients at hospital with a policy for FPDR (n=5,520) 78 hospitals	Patients at hospital without a policy for FPDR (n=12,106) 169 hospitals	P-value [*]	OR ^{**} (95% CI)	P-value
Non-pharmacologic interventions, n (%)						
Invasive airway	7,624 (43.3)	2,331 (42.2)	5,293 (43.7)	0.37	1.06 (0.88-1.28)	0.52
Blood transfusion	813 (4.6)	294 (5.3)	519 (4.3)	0.02	1.06 (0.87-1.30)	0.55
Central venous catheter	1,791 (10.2)	602 (10.9)	1,189 (9.8)	0.80	1.09 (0.78-1.52)	0.60
Chest thoracostomy tube	226 (1.3)	90 (1.6)	136 (1.1)	0.08	1.31 (0.92-1.90)	0.13
Echocardiogram	537 (3.1)	198 (3.6)	339 (2.8)	0.96	1.17 (0.70-1.97)	0.55
Transcutaneous pacemaker	1,055 (6.0)	330 (6.0)	725 (6.0)	0.95	1.03 (0.78-1.36)	0.81
Transvenous pacemaker	397 (2.3)	104 (1.9)	293 (2.4)	0.12	0.71 (0.52-0.97)	0.03
Pericardiocentesis	271 (1.5)	95 (1.7)	176 (1.5)	0.30	1.09 (0.72-1.66)	0.68
Total non-pharmacologic				0.58	1.02 (0.86-1.20)	0.85
Pharmacologic interventions, n (%)						
Amiodarone	3,086 (17.5)	1,029 (18.6)	2,057 (17.0)	0.25	1.09 (0.94-1.28)	0.26
Lidocaine	1,133 (6.4)	351 (6.4)	782 (6.5)	0.88	1.02 (0.83-1.24)	0.87
Dobutamine	722 (4.1)	251 (4.6)	471 (3.9)	0.47	1.03 (0.77-1.37)	0.84
Dopamine	4,121 (23.4)	1,310 (23.7)	2,811 (23.2)	0.86	1.01 (0.83-1.23)	0.90
Norepinephrine	4,101 (23.3)	1,557 (28.2)	2,544 (21.0)	0.04	1.46 (1.17-1.83)	0.001
Phenylephrine	1,482 (8.4)	467 (8.5)	1,015 (8.4)	0.82	0.92 (0.60-1.42)	0.71
Atropine	14,749 (83.7)	4,577 (82.9)	10,172 (84.0)	0.03	0.98 (0.78-1.23)	0.85
Calcium chloride	6,614 (37.5)	2,201 (39.9)	4,413 (36.5)	0.18	1.07 (0.89-1.28)	0.49
IV fluid bolus	6,031 (34.2)	1,932 (35.0)	4,099 (33.9)	0.53	1.01 (0.76-1.35)	0.95
Magnesium sulfate	2,071 (11.8)	736 (13.3)	1,335 (11.0)	0.71	1.26 (0.95-1.68)	0.11
Sodium bicarbonate	11,658 (66.1)	3,608 (65.4)	8,050 (66.5)	0.61	0.90 (0.78-1.05)	0.19
Total pharmacologic				0.69	0.92 (0.73-1.16)	0.48

* P-values derived from bivariate generalized linear models. These models accounted for clustering of patients within hospitals.

** Odd-ratios adjusted for patient and hospital characteristics

Appendix Table 3

Specific potential resuscitation system errors

	Unadjusted analysis				Adjusted analysis	
	All patients (n=41,568) 252 hospitals	Patients at hospital with a policy for FPDR (n=13,470) 80 hospitals	Patients at hospital without a policy for FPDR (n=28,098) 172 hospitals	P-value*	Adjusted OR (95% CI)	P-value
Alerting						
Delay in alerting code team	80 (0.2)	39 (0.3)	41 (0.2)	0.26	1.75 (0.92-3.32)	0.09
Pager Issue	45 (0.1)	23 (0.2)	22 (0.1)	0.20	2.39 (0.97-5.86)	0.06
Other	124 (0.3)	42 (0.3)	82 (0.3)	0.47	1.00 (0.52-1.94)	0.99
Airway						
Aspiration	49 (0.1)	18 (0.1)	31 (0.1)	0.86	1.24 (0.52-2.94)	0.62
Airway insertion delay	325 (0.8)	163 (1.2)	162 (0.6)	0.40	2.11 (1.06-4.20)	0.03
Delayed recognition of airway misplacement	22 (0.05)	7 (0.05)	15 (0.05)	0.96	0.88 (0.33-2.37)	0.80
Attempted, not achieved	81 (0.2)	31 (0.2)	50 (0.2)	0.99	1.45 (0.79-2.67)	0.23
Multiple attempts	792 (1.9)	307 (2.3)	485 (1.7)	0.95	1.41 (0.92-2.17)	0.12
Other	292 (0.7)	107 (0.8)	1856 (0.7)	0.53	1.45 (0.96-2.20)	0.08
Vascular access						
Delay	158 (0.4)	68 (0.5)	90 (0.3)	0.28	1.87 (1.15-3.03)	0.01
IV infiltration or disconnected	81 (0.2)	36 (0.3)	45 (0.2)	0.09	1.74 (1.10-2.74)	0.02
Other	108 (0.3)	42 (0.3)	66 (0.2)	0.49	1.49 (0.82-2.70)	0.19
Chest Compression						
Rate of 100/min not maintained	5,608 (13.5)	1,630 (12.1)	3,978 (14.2)	0.35	0.92 (0.50-1.71)	0.80
Interruptions of >10 sec at any time	295 (0.7)	117 (0.9)	178 (0.6)	0.39	1.34 (0.55-3.31)	0.52
Delay in starting	211 (0.5)	110 (0.8)	101 (0.4)	0.23	2.14 (0.71-6.45)	0.18
No board used	33 (0.08)	15 (0.1)	18 (0.06)	0.52	1.63 (0.44-6.04)	0.46
Other	121 (0.3)	40 (0.3)	81 (0.3)	0.88	1.22 (0.61-2.46)	0.57
Defibrillation						
Personnel issue causing delay >2 minutes	3 (0.01)	2 (0.01)	1 (0.0)	0.24	9.07 (1.89-43.6)	0.006
Energy level incorrect	204 (0.5)	61 (0.5)	143 (0.5)	0.17	1.23 (0.57-2.68)	0.59
Incorrect placement of pads/paddles	21 (0.05)	6 (0.04)	15 (0.05)	0.71	0.80 (0.21-3.11)	0.75
Malfunction	16 (0.04)	10 (0.07)	6 (0.02)	0.04	3.33 (0.97-11.4)	0.06
Shock given, not indicated	210 (0.5)	46 (0.3)	164 (0.6)	0.03	0.65 (0.33-1.26)	0.20
Shock indicated, not given	164 (0.4)	48 (0.4)	116 (0.4)	0.29	1.01 (0.46-2.22)	0.98
Other	325 (0.8)	158 (1.2)	167 (0.6)	0.299	2.08 (1.07-4.03)	0.03
Medications						
Vasopressor delay >5 minutes from event recognition	548 (1.3)	220 (1.6)	328 (1.2)	0.45	1.49 (0.60-3.70)	0.39
Wrong route of administration	314 (0.8)	174 (1.3)	140 (0.5)	0.43	2.74 (0.84-8.94)	0.10

	Unadjusted analysis				Adjusted analysis	
	All patients (n=41,568) 252 hospitals	Patients at hospital with a policy for FPDR (n=13,470) 80 hospitals	Patients at hospital without a policy for FPDR (n=28,098) 172 hospitals	P-value*	Adjusted OR (95% CI)	P-value
Wrong dosage	363 (0.9)	120 (0.9)	243 (0.9)	0.88	1.13 (0.29-4.33)	0.86
Wrong medication selection	442 (1.1)	234 (1.7)	208 (0.7)	0.93	2.56 (1.00-6.53)	0.05
Code team leadership						
Delay in identifying team leader	64 (0.2)	28 (0.2)	36 (0.1)	0.72	1.56 (0.61-3.99)	0.35
Knowledge of equipment	26 (0.06)	9 (0.07)	17 (0.06)	0.88	1.17 (0.48-2.85)	0.73
Knowledge of medications/protocol	203 (0.5)	48 (0.4)	155 (0.6)	0.46	1.73 (0.76-3.94)	0.20
Knowledge of team member roles	48 (0.1)	15 (0.1)	33 (0.1)	0.82	1.11 (0.26-4.74)	0.89
Code team oversight	25 (0.06)	6 (0.04)	19 (0.07)	0.41	0.63 (0.21-1.88)	0.40
Too many individuals in room	13 (0.3)	69 (0.5)	64 (0.2)	0.23	1.99 (0.72-5.50)	0.18
Protocol to ACLS guidelines						
Deviation	809 (2.0)	209 (1.6)	600 (2.1)	0.38	0.78 (0.32-1.94)	0.60
Other	43 (0.1)	19 (0.1)	24 (0.1)	0.29	1.71 (0.59-5.03)	0.32
Equipment issues						
Availability	204 (0.5)	98 (0.7)	106 (0.4)	0.40	1.89 (0.99-3.62)	0.05
Malfunction	111 (0.3)	50 (0.4)	61 (0.2)	0.29	1.85 (0.80-4.26)	0.15
Other	105 (0.3)	44 (0.3)	61 (0.2)	0.28	1.64 (0.74-3.63)	0.22

* P-values derived from bivariate regression models using generalized-estimation equations with a robust variance estimate. These models accounted for clustering of patients within hospitals.

** Adjusted for patient and hospital characteristics

Appendix Table 4

Risk Model

Patient variables

- “Shockable” initial pulseless rhythms (pulseless VT and VF)
- Age
- Race (black, non-black)
- Gender
- Illness category (medical non-cardiac, medical cardiac, surgical cardiac, surgical non-cardiac and trauma, obstetric, and other)
- Pre-existing conditions (none, myocardial infarction during hospitalization, hypotension/hypoperfusion, hepatic insufficiency, baseline depression in central nervous system function, acute stroke, infection or septicemia, metastatic or hematologic malignancy, diabetes mellitus, renal failure, major trauma)
- Interventions in place at the time of cardiac arrest (invasive airway, chest tube, assisted or mechanical ventilation, vasopressors, vasodilators)
- Monitoring with an arterial line
- Witnessed arrest
- Event location (intensive care unit, general floor/telemetry)
- Time from identification of pulselessness to the start of compressions

Hospital-level covariates

- Location
- Region (Northern-Mid Atlantic, South Atlantic, South Central, North Central, Mountain/Pacific)
- Bed size
- Ownership (non-profit, state, church, local government, VA/military)
- Residency/teaching status
- Member of a health care system
- Presence of an emergency department
- Cardiac surgery service available

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Figure 1.
Study cohort

Table 1

Hospital characteristics

	All hospitals (n=252)	Hospitals with FPDR policy (n=80)	Hospitals without FPDR policy (n=172)	P-value *
Location, n (%)				0.49
Urban	225 (89.3)	73 (91.3)	152 (88.4)	
Rural	27 (10.7)	7 (8.8)	20 (11.6)	
Ownership n (%)				0.22
Nonprofit	133 (52.8)	50 (62.5)	83 (48.3)	
Church	45 (17.9)	9 (11.3)	36 (20.9)	
State	33 (13.1)	10 (12.5)	23 (13.4)	
Local government	36 (14.3)	9 (11.3)	27 (15.7)	
VA/military	5 (2.0)	2 (2.5)	3 (1.7)	
Bedsized, n (%)				0.40
<100	17 (6.8)	4 (5.0)	13 (7.6)	
100-199	57 (22.6)	15 (18.8)	42 (24.4)	
200-249	26 (10.3)	7 (8.8)	19 (11.1)	
250-299	21 (8.3)	10 (12.5)	11 (6.4)	
300-349	26 (10.3)	11 (13.8)	15 (8.7)	
350-499	49 (19.4)	13 (16.3)	36 (20.9)	
500	56 (22.2)	20 (25.0)	36 (20.9)	
Region, n (%)				0.29
North Mid-Atlantic	38 (15.1)	13 (16.3)	25 (14.5)	
South Atlantic	63 (25.0)	14 (17.5)	49 (28.5)	
North Central	54 (21.4)	20 (25.0)	34 (19.8)	
South Central	46 (18.3)	13 (16.3)	33 (19.2)	
Mountain/Pacific	51 (20.2)	20 (25.0)	31 (18.0)	
Other characteristics, n (%)				
Residency (yes)	122 (48.4)	44 (55.0)	78 (45.4)	0.16
Emergency Dept present	249 (98.8)	79 (98.8)	170 (98.8)	0.95
Trauma center (yes)	145 (57.5)	46 (57.5)	99 (57.6)	0.99
Heart transplant center	34 (13.5)	11 (13.8)	23 (13.4)	0.94
Urgent care present	95 (37.7)	28 (35.0)	67 (39.0)	0.55
Cardiac surgery (yes)	168 (66.7)	57 (71.3)	111 (64.5)	0.29
Cardiac rehab (yes)	196 (77.8)	69 (86.3)	127 (73.8)	0.03
Ambulance services	56 (22.2)	15 (18.8)	41 (23.8)	0.37
Member of health care system (yes)	167 (66.3)	51 (63.8)	116 (67.4)	0.57

* P-values derived from univariate generalized linear models. These models accounted for clustering of patients within hospitals.

TABLE 2

Patient Characteristics

	All patients (n=41,568) 252 hospitals	Patients at hospitals with FPDR policy (n=13,470) 80 hospitals	Patients at hospitals without FPDR policy (n=28,098) 172 hospitals	P-value *
Age				0.12
Mean age (SD)	65.2 (16.2)	64.2 (16.5)	65.6 (16.0)	
Female Sex	17,660 (42.5)	5,669 (42.1)	11,991 (42.7)	0.44
Race, n (%)				0.58
White	30,083 (72.4)	9,975 (74.1)	20,108 (71.6)	
Black	9,635 (23.2)	2,791 (20.7)	6,844 (24.4)	
Asian/Pacific Islander	724 (1.7)	306 (2.3)	418 (1.5)	
American Indian/Eskimo/Aleutian	227 (0.6)	86 (0.6)	141 (0.5)	
Other	899 (2.2)	312 (2.3)	587 (2.1)	
Pre-existing conditions, n (%)				
Renal insufficiency	15,115 (36.4)	4,761 (35.6)	10,354 (36.9)	0.23
Hepatic insufficiency	3,534 (8.5)	1,267 (9.4)	2,267 (8.1)	0.46
Malignancy	5,271 (12.7)	1,729 (12.8)	3,542 (12.6)	0.83
Decrease in CNS function	5,072 (12.2)	1,850 (13.7)	3,222 (11.5)	0.48
Septicemia	8,112 (19.5)	2,720 (20.2)	5,392 (19.2)	0.92
Major trauma	1,895 (4.6)	669 (5.0)	1,226 (4.4)	0.31
Acute stroke	1,583 (3.8)	503 (3.7)	1,080 (3.8)	0.82
None	1,759 (4.2)	495 (3.7)	1,264 (4.5)	0.21
Hypotension/hypoperfusion	12,558 (30.2)	4,389 (32.6)	8,169 (29.1)	0.65
Metabolic abnormality	7,234 (17.4)	2,250 (16.7)	4,984 (17.7)	0.84
Arrhythmia	14,330 (34.5)	4,468 (33.2)	9,862 (35.1)	0.73
MI during admission	6,912 (16.6)	2,250 (16.7)	4,662 (16.6)	0.97
MI on a prior admission	5,889 (14.2)	1,850 (13.7)	4,039 (14.4)	0.82
Respiratory insufficiency	19,141 (46.1)	6,256 (46.4)	12,885 (45.9)	0.69
Pneumonia	6,212 (14.9)	2,025 (15.0)	4,187 (14.9)	0.76
Diabetes mellitus	13,134 (31.6)	4,124 (30.6)	9,010 (31.1)	0.09
CHF this admission	7,281 (17.5)	2,557 (19.0)	4,724 (16.8)	0.13
CHF on prior admission	8,093 (19.5)	2,678 (19.9)	5,415 (19.3)	0.73
Critical care interventions in place at time of arrest, n (%)				
Assisted/mechanical ventilation	17,192 (41.4)	5,897 (43.8)	11,295 (40.2)	0.52
Invasive airway	16,047 (38.6)	5,317 (39.5)	10,730 (38.2)	0.77
Vasopressors	15,156 (36.5)	4,852 (36.0)	10,304 (36.7)	0.90
Antiarrhythmics	3,452 (8.3)	1,111 (8.3)	2,341 (8.3)	0.41
Vasodilators	355 (0.9)	99 (0.7)	256 (0.9)	0.29
Arterial line	5,635 (13.6)	2,008 (14.9)	3,627 (12.9)	0.26
Amiodarone	2,772 (6.7)	910 (6.7)	1,862 (6.6)	0.48
Chest tube	1,442 (3.5)	530 (3.9)	912 (3.3)	0.15

	All patients (n=41,568) 252 hospitals	Patients at hospitals with FPDR policy (n=13,470) 80 hospitals	Patients at hospitals without FPDR policy (n=28,098) 172 hospitals	P-value *
Location, n (%)				0.92
ICU	24,342 (65.7)	7,902 (65.6)	16,440 (65.8)	
General floor/telemetry	12,684 (34.3)	4,141 (34.4)	8,543 (34.2)	
VT/VF, n (%)	7,207 (17.3)	2,292 (17.0)	4,915 (17.5)	0.86
Illness category, n (%)				0.07
Medical/cardiac	13,666 (32.9)	4,634 (34.4)	9,032 (32.1)	
Medical/noncardiac	19,418 (46.7)	6,103 (45.3)	13,315 (47.4)	
Surgical/cardiac	2,540 (6.1)	793 (5.9)	1,747 (6.2)	
Surgical/noncardiac and trauma	4,479 (10.8)	1,384 (10.3)	3,095 (11.0)	
Trauma	1,397 (3.4)	522 (3.9)	875 (3.1)	
Obstetric	16 (0.04)	10 (0.07)	6 (0.02)	
Other	52 (0.1)	24 (0.2)	28 (0.1)	
Witnessed arrest, n (%)	35,193 (84.7)	11,323 (84.1)	23,870 (85.0)	0.92

* P-values derived from bivariate regression models using generalized-estimation equations with a robust variance estimate. These models accounted for clustering of patients within hospitals.

TABLE 3a

Unadjusted risk ratios by hospital policy for FPDR

Outcome	Unadjusted risk ratio (95% CI)		
	Total Cohort	VF/VT	PEA/ Asystole
ROSC	1.04 (1.00-1.09)	0.99 (0.93-1.06)	1.05 (1.01-1.10)
Survival to discharge	1.07 (0.96-1.20)	1.05 (0.95-1.16)	1.00 (0.96-1.04)
Discharged with favorable neurologic status	0.98 (0.92-1.04)	1.00 (0.95-1.05)	0.97 (0.90-1.04)

TABLE 3b

Adjusted risk ratios by hospital policy for FPDR

Outcome	Adjusted risk ratio (95% CI) [*]		
	Total Cohort	VF/VT	PEA/ Asystole
ROSC	1.02 (0.98-1.06)	0.99 (0.95-1.03)	1.03 (0.99-1.07)
Survival to discharge	1.05 (0.95-1.15)	1.05 (0.95-1.16)	1.06 (0.95-1.19)
Discharged with favorable neurologic status	0.97 (0.92-1.02)	0.99 (0.94-1.03)	0.96 (0.90-1.02)

* Adjusted for patient and hospital characteristics

Table 4

Association between FPDR and resuscitation characteristics

	Unadjusted analysis			Adjusted analysis	p-value
	FDPR	No FDPR	p-value *	Effect size for hospital policy of FDPR vs. no FPDR (95% CI) **	
Code Quality					
Median duration of resuscitation in non-survivors, (IQR)	21 (19-23)	21 (19-24)	0.048	Mean difference −1.4 min (−2.7 to −0.08)	0.04
Time to defibrillation, mean (95% CI)	2.1 (2.0-2.3)	2.4 (2.2-2.5)	0.03	Mean difference −0.32 (−0.64 to −0.01)	0.05
Number of shocks delivered, median (IQR)	2 (1-3)	2 (1-4)	0.53	Mean difference −0.05 (−0.21 to 0.04)	0.45
Received compressions (%)	98.4	98.3	0.75	Odds ratio 1.17 (0.71 to 1.93)	0.54
Interventions Delivered During Code, Categories (%)					
Pharmacologic	92.7	92.8	0.24	Odds Ratios ** (95% CI) 0.89 (0.77-1.04)	0.15
Non-Pharmacologic	53.3	52.7	0.09	1.03 (0.92-1.17)	0.59
Potential Resuscitation System Error Groups, Categories (%)					
Alerting	0.7	0.5	0.93	1.38 (0.76-2.50)	0.29
Airway	3.9	2.8	0.87	1.53 (0.98-2.39)	0.06
Vascular access	1.0	0.6	0.52	1.74 (1.17-2.60)	0.007
Chest compressions	13.4	15.0	0.47	0.96 (0.54-1.72)	0.90
Defibrillation	2.3	2.0	0.32	1.28 (0.72-2.25)	0.40
Medications	5.0	2.7	0.83	2.04 (1.01-4.14)	0.047
Code team leadership	1.1	1.0	0.99	1.95 (0.86-4.41)	0.11
Equipment	1.3	0.7	0.22	1.84 (0.90-3.43)	0.06
Protocol to ACLS guidelines	1.7	2.2	0.44	0.81 (0.34-1.96)	0.65
All potential error groups	23.1	20.8	0.34	1.26 (0.81-1.96)	0.31

* P-values derived from bivariate generalized linear models. These models accounted for clustering of patients within hospitals.

** Odd-ratios adjusted for patient and hospital characteristics