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Ratio of Pediatric ICU versus Ward Cardiopulmonary Resuscitation Events is Increasing

Robert A. Berg, MD FCCM, Robert M. Sutton, MD FCCM, Richard Holubkov, PhD, Carol E. Nicholson, MD, J. Michael Dean, MD FCCM, Rick Harrison, MD FCCM, Sabrina Heidemann, MD, Kathleen Meert, MD, Christopher Newth, MD ChB, Frank Moler, MD, Murray Pollack, MD FCCM, Heidi Dalton, MD FCCM, Allan Doctor, MD FCCM, David Wessel, MD, John Berger, MD, Thomas Shanley, MD, Joseph Carcillo, MD FCCM, and Vinay M. Nadkarni, MD FCCM for the Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network for the American Heart Association's Get With the Guidelines®-Resuscitation (formerly the National Registry of Cardiopulmonary Resuscitation) Investigators

The Children's Hospital of Philadelphia and The University of Pennsylvania Perelman School of Medicine (Drs. Berg, Sutton, and Nadkarni), University of Utah (Drs. Dean and Holubkov); National Institute of Child Health and Human Development (Dr. Nicholson); University of California at Los Angeles (Dr. Harrison); Children's Hospital of Michigan (Drs. Heidemann and Meert); Children's Hospital Los Angeles (Dr. Newth); University of Michigan and Mott Children's Hospital (Drs. Moler and Shanley); Phoenix Children's Hospital (Drs. Pollack and Dalton); Washington University School of Medicine (Dr. Doctor); Children's National Medical Center (Drs. Wessel and Berger); Children's Hospital of Pittsburgh of UPMC (Dr. Carcillo)

Abstract

Objective—The aim of this study was to evaluate the relative frequency of pediatric in-hospital CPR events occurring in intensive care units (ICUs) compared to general wards. We hypothesized that the proportion of pediatric CPR provided in ICUs versus general wards has increased over the past decade and this shift is associated with improved resuscitation outcomes.

Design—Prospective, observational study.

Setting—Total of 315 hospitals in the American Heart Association's Get With The Guidelines-Resuscitation (GTWG-R) database.

Corresponding Author: Robert A. Berg, MD, The Children's Hospital of Philadelphia, 34th Street & Civic Center Blvd, 7 South Tower-Rm#7C26, Philadelphia, PA 19104-4399; bergra@email.chop.edu; 267-426-3014; FAX 215-590-4327.

Get With The Guidelines-Resuscitation Investigators: Besides the authors Robert A. Berg, MD, Heidi Dalton, MD, Frank Moler, MD, and Vinay Nadkarni, MD, members of the Get With The Guidelines-Resuscitation Clinical Work Group and Pediatrics Task Force include: Paul S. Chan, MD, MSc, Mid America Heart Institute and the University of Missouri; Mary Mancini, RN, PhD, University of Texas at Arlington; Emilie Allen, MSN, RN, Parkland Health and Hospital System; Robert Clark, MD, University of Pittsburgh Medical Center; Michael W. Donnino, MD, Beth Israel Deaconess Medical Center; Brian Eigel, PhD and Lana Gent, PhD, American Heart Association; Robert T. Faillace, MD, St. Joseph's Regional Center; Elizabeth A. Hunt, MD, MPH, PhD, Johns Hopkins Medicine Simulation Center; Lynda Knight, RN, Lucile Packard Children's Hospital at Stanford; Kenneth LaBresh, RTI International; Peter C. Laussen, MB BS, Children's Hospital Boston; Marilyn Morris, MD, Children's Hospital of New York; Graham Nichol, MD, MPH, University of Washington-Harborview Medical Center; Joseph P. Ornato, MD and Mary Ann Peberdy, MD, Virginia Commonwealth University Medical Center; Chris Parshuram, MD, The Hospital for Sick Children; Comilla Sasson, MD, MS, University of Colorado; Mindy Smyth, MSN, RN; and Arno L. Zaritsky, MD, Children's Hospital of the King's Daughters.

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Work was performed at all of the authors' institutions and all of the Get With The Guidelines-Resuscitation hospitals.

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Patients—Total of 5,870 pediatric cardiopulmonary resuscitation (CPR) events between January 1, 2000 and September 14, 2010. CPR events were defined as external chest compressions >1minute.

Measurements and Results—The primary outcome was proportion of total ICU versus general ward CPR events over time evaluated by chi square test for trend. Secondary outcome included return of spontaneous circulation (ROSC) following the CPR event. Among 5870 pediatric CPR events, 5477 (93.3%) occurred in ICUs compared to 393 (6.7%) on inpatient wards. Over time, significantly more of these CPR events occurred in the ICU compared to the wards (test for trend: $p<0.01$), with a prominent shift noted between 2003 and 2004 (2000-2003: 87 - 91% vs. 2004-2010: 94 - 96%). In a multivariable model controlling for within center variability and other potential confounders, ROSC increased in 2004-2010 compared with 2000-2003 (RR 1.08, 95% confidence interval: 1.03-1.13).

Conclusions—In-hospital pediatric CPR is much more commonly provided in ICUs vs. Wards and the proportion has increased significantly over the past decade with concomitant increases in return of spontaneous circulation.

Keywords

Cardiac arrest; cardiopulmonary resuscitation; CPR; intensive care; pediatrics; children

Introduction

More than 4,000 children in the USA receive in-hospital cardiopulmonary resuscitation (CPR) each year, mostly in pediatric intensive care units.¹⁻⁵ Because many of these events are a result of progressive respiratory failure and circulatory shock, early warning systems and rapid response teams have been developed for earlier recognition, treatment and transfer to pediatric intensive care units (PICUs).⁴⁻¹⁰ These changes were implemented in order to decrease the proportion of cardiac arrests occurring in less intensely monitored settings and to improve outcomes by preventing cardiac arrests and providing higher quality CPR in the resource-intensive specialized environment of the PICU.

Since 2007, two single center pediatric studies demonstrated that rapid response teams decreased the incidence of cardiac arrests on inpatient wards and improved survival.^{8,9} Not surprisingly, the Institute for Healthcare Improvement and the Child Healthcare Corporation of America now consider pediatric CPR events on general wards as sentinel events to be avoided in safe, high quality hospital environments.^{10,11} However, implementation of best practices on a large scale is difficult.¹⁰

The aim of this study is to evaluate the relative frequency of pediatric in-hospital CPR events occurring in intensive care units (ICUs) compared to general wards and to determine whether the proportion of pediatric in-hospital CPR events occurring in the ICU compared to general wards has increased over the last decade. We hypothesized that the proportion of CPR provided in ICUs versus wards increased. We further hypothesized that resuscitation outcomes would improve if the proportion of ICU-to-ward CPR events increased. We addressed these hypotheses through analysis of in-hospital pediatric CPR events reported to the American Heart Association's large multi-center Get-With-The-Guidelines-Resuscitation (GWTG-R) registry database from 2000-2010.

Methods

Get With The Guidelines-Resuscitation (formerly known as the National Registry of Cardiopulmonary Resuscitation or NRCPR) is an American Heart Association sponsored

prospective multisite registry of patients undergoing in-hospital resuscitation. Hospitals voluntarily participate in the database for the primary purpose of quality improvement, and as such are not required to obtain institutional review board (IRB) approval or informed consent from patients or families. The present study was exempted from IRB oversight at the Children's Hospital of Philadelphia.

Inclusion and Exclusion Criteria

Three hundred and fifteen hospitals provided data regarding pediatric in-hospital CPR to this registry from January 2000 to September 2010. All patients under 18 years of age with a CPR event requiring chest compressions for >1 minute at a participating hospital were eligible for inclusion.⁵ Events with shorter duration of chest compressions were excluded to avoid brief exposures to chest compressions that may not have been necessary. According to GWTG-R operational definitions, a CPR event is any event characterized by either pulselessness or critically compromised perfusion treated with external chest compressions, when a unit-wide or hospital-wide emergency response was activated. Events commencing out-of-hospital and events in any location besides a ward or ICU were excluded (e.g., delivery suite, newborn ICU, post-anesthesia care unit, emergency department, procedural and surgical suites).

Study Outcome Measures

The primary study outcome was proportion of total ICU versus general ward CPR events. Secondary outcomes included resuscitation outcomes: ROSC for at least 20 minutes after the CPR event, 24-hour survival from the event, survival to hospital discharge, and survival to hospital discharge with a favorable neurological outcome. As per the international guidelines,¹² ROSC and 24-hour survival were reported for each CPR event. Survival to discharge and favorable neurological outcomes among survivors were reported for the index (or first) CPR event for each patient because a patient can only survive to discharge once per hospitalization.¹² Neurological outcomes were assessed using previously validated pediatric cerebral performance category (PCPC) scores.¹²⁻¹⁴ A PCPC score of 1 describes children with normal age-appropriate neuro-developmental functioning; 2 for mild cerebral disability; 3 for moderate disability; 4 for severe disability; 5 for coma/vegetative state, and 6 for brain death. Favorable neurological outcome was defined as a PCPC score of 1-3 at discharge or no increase compared to admission PCPC status.¹⁴

Study Variables

The main independent variable was the calendar year in initial analyses. In further analyses, the independent variable was 2000-2003 period versus 2004-2010. As noted in Table 1, other factors analyzed were: 1) patient factors, including demographics, pre-existing conditions, and illness categories; 2) arrest characteristics, including interventions in place at time of arrest, first documented rhythm, immediate cause of arrest, time of arrest, duration of CPR, witnessed/monitored status, and pharmacologic interventions; and 3) resuscitation outcomes. In addition, several hospital variables potentially related to outcome were analyzed, including number of pediatric ward beds (>30 versus ≤30), number of pediatric ICU beds (>20 versus ≤20), approved pediatric residency program, pediatric cardiac surgery program, and level 1 trauma center.¹⁵

Statistical analysis

Significance of association of binary factors with year of arrest was assessed by the Mantel-Haenszel test for trend for ordered categorical factors. Evidence of association of outcome factors with arrest location (ICU vs. Ward) or ICU time period (2000-2003 vs. 2004-2010) was assessed by Pearson chi-squared test for binary and unordered categorical factors, and

with the Mantel-Haenszel test for trend for ordered categorical factors. Significance of association of continuous factors with arrest location or ICU time-period was assessed by the Wilcoxon test.

Relative risk of binary outcomes for 2000-2003 versus 2004-2010 admissions was assessed using modified Poisson regression, which produces rate ratios together with robust variance estimates.¹⁶ Models were fit using Generalized Estimating Equations (GEE) to account for within-institution clustering of patients; these GEE models used an exchangeable correlation matrix. In reported multivariable models, all categorical pre-arrest status variables and hospital-level variables displaying a trend ($p < 0.15$) towards unadjusted association with the modeled outcome were included as covariates. All statistical analyses were conducted using SAS Version 9.2 (SAS Institute, Cary, NC). All reported tests for statistical significance are two-tailed.

Data Integrity

Data integrity was maintained using a detailed periodic re-abstraction process. GWTG-R participating hospitals submitted randomly selected records each quarter, and a random sampling of event records and corresponding GWTG-R data sheets were re-abstracted and reviewed for errors by GWTG-R oversight committee. Mean (SD) error rates for all data were 2.5% (+2.7%). Web-based remediation was utilized to support data integrity continuously for enrolling sites. Enrollment of new hospitals as contributors to the database requires certification by testing accuracy of data collection before allowing data submission centrally.

Results

Between January 1, 2000 and September 14, 2010, 7,877 CPR events in pediatric subjects < 18 years of age at 315 hospitals were reported to the GWTG-R registry excluding CPR events in the NICU, Delivery Room, and newborn nursery. After 706 CPR events in Emergency Departments, 382 CPR events in Operating Room complexes, 459 CPR events in other non-ICU/non-ward settings, and 460 CPR events from hospitals with less than 3 years of data were excluded, we evaluated 5870 CPR events at 98 hospitals that occurred in an ICU or a general ward at a hospital contributing at least 3 years of data in which an eligible event occurred (Figure 1).

Among these 98 hospitals, 59 provided 2829 events spread over both periods, 4 provided 125 events only for the 2000-3 interval, and 35 provided 1531 events only for the 2004-2010 interval. Of these 5870 CPR events, 5477 (93.3%) occurred in ICUs compared to 393 (6.7%) on general wards. Over time, a significantly higher proportion of these CPR events occurred in the ICU compared to general wards (test for trend: $p < 0.01$), with a prominent shift noted between 2003 and 2004 (2000-03: 87-91% vs. 2004-10: 94-96%; Figure 2).

Table 1 displays baseline subject characteristics with comparisons between the ICU CPR events and general ward CPR events, and between 2000-03 and 2004-10 time periods as defined in Figure 2. Table 2 shows unadjusted survival outcomes. By univariate analysis, ROSC, 24-hour survival, and favorable neurological outcome among survivors were all significantly higher for 2004-10 versus 2000-03. Using a multivariable model controlling for between center variability and other potential pre-arrest confounders, the rate of ROSC following all CPR events (RR 1.08, CI⁹⁵ 1.03-1.13) was higher in 2004-10 compared to 2000-03, and the rate of favorable neurological outcomes among survivors was also higher (RR 1.035, CI⁹⁵ 1.0005-1.07). For the other outcomes considered, estimated adjusted risk ratios for 2004-10 versus 2000-03 were not significantly different from unity.

Discussion

For these 5870 pediatric in-hospital CPR events from 2000-10 in the Get With The Guidelines-Resuscitation registry, 93% of the CPR events occurred in ICUs versus only 7% in general pediatric wards. As expected, the ratio of ICU-to-ward CPR increased substantially over this decade with 9-13% occurring on wards from 2000-03 and 4-6% occurring on wards from 2004-10. Importantly, successful initial resuscitation for these pediatric in-hospital CPR events (ROSC) increased concomitantly with the increase in ratio of ICU-to-ward CPR events from 2004-10, as did favorable neurological outcomes among survivors.

Although previous studies had shown that in-hospital pediatric CPR is less commonly performed in ward settings compared with ICU settings, those investigations demonstrated that 14-18% of the combined ward and ICU CPR events were performed in ward settings.⁴⁻⁶ In contrast, these GWTG-R hospitals successfully decreased pediatric ward CPR to <6% of the combined CPR events in pediatric wards and ICUs since 2003. Interestingly, adult GWTG-R data from 2000-2008 reveal that >40% of adult CPR was provided on wards versus ICUs.¹⁷

What is the importance of this increased ratio of ICU-to-ward pediatric CPR? The ultimate goals of shifting pediatric patients to a critical care setting before the need for CPR are to: 1) prevent CPR by critical care monitoring and prompt therapeutic interventions and 2) increase the likelihood of survival following CPR when it is needed. Although the GWTG-R database provides substantial information about CPR events, it is not designed to address whether CPR events were avoided. For example, the database does not include hospital admission or census information, or information about patient severity of illness. Nevertheless, the resuscitation outcome data in this study revealed higher rates of ROSC in 2004-10 versus 2000-03, concomitant with the increase in the ratio of ICU-to-ward CPR events. In addition, there was a trend toward higher rates of favorable neurological outcomes among survivors in 2004-2010 compared with 2000-2003. These observational data cannot address the issue of whether this improvement in successful resuscitations was due to the relative shift of these events from the ward-to-ICU versus secular changes in the effectiveness of resuscitation practices or some other factors. Compared with ward environments, ICU environments are more resource intense with a greater staff-to-patient ratio, and more of the ICU personnel presumably have recent CPR training, experience and expertise. Therefore, one plausible explanation for the improvement in successful resuscitations is the shift to more CPR events in the ICU.

Table 2 shows that ROSC and survival to discharge occurred more commonly following ward CPR events compared with ICU CPR events. Of course, patients were on the ward rather than the ICU because their physicians determined that they were less sick and thereby did not need ICU care. Not surprisingly, Table 1 demonstrates that the ward CPR cohort was much less likely to have important pre-arrest problems, including hypotension, respiratory failure, major trauma, and congestive heart failure. Furthermore, the ICU cohort was much more likely to receive prearrest intensive care therapies, such as vasoactive infusions and assisted ventilation. Perhaps the patients with ward CPR events would have had an even higher rate of ROSC and survival to discharge if their CPR events were in the resource intense ICU environment. Importantly, the overall rate of ROSC following all CPR events was higher in the 2004-10 period when the relative rate of ICU CPR events was higher.

Although two before-and-after single center studies showed improvements in pediatric overall survival after Medical Emergency Team (AKA Rapid Response Team) implementation, a larger multi-center pediatric observational study was unable to

demonstrate similar improvements in survival after pediatric Medical Emergency Team implementation.¹⁰ While it is tempting to attribute the shift in proportion of ICU CPR events and the improved resuscitation outcomes to increasing implementation of early warning systems and Medical Emergency Teams, the limited data in the GWTG-R database and the study design preclude such attributions.

These GWTG-R data indicating that pediatric in-hospital CPR events are much more common in ICUs compared with wards have important training implications. The present American Heart Association model trains all in-hospital pediatric providers to the same standard (e.g., Basic Life Support and Pediatric Advanced Life Support guidelines and courses). Because in-hospital pediatric CPR events occur more commonly in highly monitored ICUs than wards, perhaps the focus of pediatric advanced life support (PALS) training should be concentrated on the PICU staff and train these ICU providers to use available intensive monitoring (e.g., invasive arterial catheters and capnometry) to guide resuscitation quality when a CPR event occurs. Conversely, as general ward CPR events are becoming less common, perhaps the training of ward providers should focus on recognizing changes in the physiologic status of patients, preventing progression to cardiac arrest, and transitioning deteriorating patients to higher levels of care before cardiac arrest occurs. When the rare CPR event occurs in a pediatric ward, those providers should be trained to provide excellent basic life support skills (BLS) until the highly trained expert ICU teams arrive for higher level advanced life support. Such a nuanced approach could lead to a more efficient and more effective life support training model by matching education and training to the predominant needs of the care providers in each setting.

Because CPR events are much more common in the ICU compared with pediatric wards, the PICU setting is especially fertile and relevant for in-hospital pediatric CPR investigations. In addition, the highly monitored ICU environment provides an opportunity to investigate the effect of attaining hemodynamic goals such as arterial blood pressures and end-tidal carbon dioxide concentrations on outcomes following CPR. Animal data have established that attaining thresholds of myocardial oxygen delivery during CPR and the highly related thresholds of coronary perfusion pressure are the primary determinants of outcomes following CPR.¹⁸ Similarly, animal data have shown that end-tidal carbon dioxide concentration is useful as another surrogate of adequate flow during CPR.¹⁸ In addition, adult out-of-hospital CPR data have demonstrated that CPR is futile when the end-tidal carbon dioxide concentrations remain <10mmHg during CPR.¹⁸ The Eunice Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network (CPCCRN) investigators embarked on this study of ICU to ward CPR event prevalence as preliminary data to focus on these important research issues. Of particular relevance for future studies of the effect of hemodynamic parameters on outcomes from PICU CPR, these data in Table 1 show that patients with ICU CPR events had arterial catheters in place prior to 39% of the CPR events and mechanical ventilation prior to 76% of the CPR events, suggesting that investigations to determine the value of arterial blood pressure measurements and capnometry during CPR are feasible goals.

Limitations

Limitations of our study are similar to those seen in all studies using large multicenter databases. Analysis of the data may be limited by data integrity and validation issues at the multiple sites submitting data to the registry. The rigorous abstractor training and certification process, uniform data collection, consistent definitions, re-abstraction data validation processes, and large sample size, unique to GWTG-R, are intended to minimize these sources of study bias. Participation in GWTG-R is voluntary; nearly 15% of the hospitals in the United States are represented in this database. It is possible that outcomes may be different at nonparticipating institutions, and this report does not reflect outcomes at

those institutions. For example, hospitals that participate in GWTG-R may also have processes in place to improve CPR outcomes. The GWTG-R hospital participation changed over time. Nevertheless, we attempted to address related potentially confounding factors by adjusting our analyses for hospital level characteristics, as well as patient factors and arrest characteristics. Because these GWTG-R data do not include overall hospital ward and/or ICU census data, we could not address whether CPR rates are increasing or decreasing overall or in the ICU or ward settings. Instead we could only show that the ratio of ICU-to-ward CPR events is increasing. More hospital level details would increase the versatility of the GWTG-R database; however, the logistics involved in requiring these hospitals to gather more data for a volunteer CQI program is problematic.

In conclusion, 93% of pediatric ICU and ward CPR events from 2000-10 in GWTG-R hospitals occurred in ICUs. The ratio of ICU-to-ward CPR increased substantially over this decade with 9-13% occurring on wards from 2000-03 and 4-6% occurring on wards from 2004-10. The rates of successful initial resuscitation from these pediatric ICU and ward CPR events (i.e., ROSC) increased in 2004-10 compared with 2000-03, concomitant with the change in ratio of ICU-to-Ward CPR event rate.

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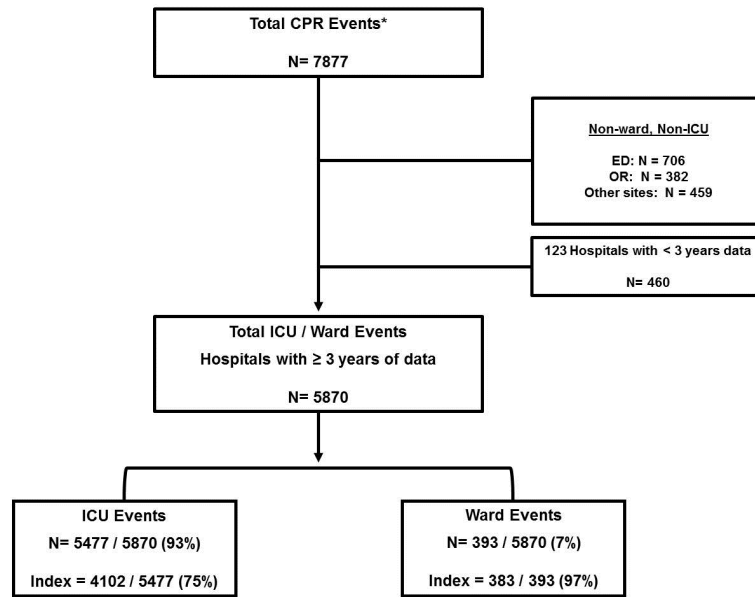


Figure 1. Utstein consort diagram. CPR, cardiopulmonary resuscitation; ICU, intensive care unit.

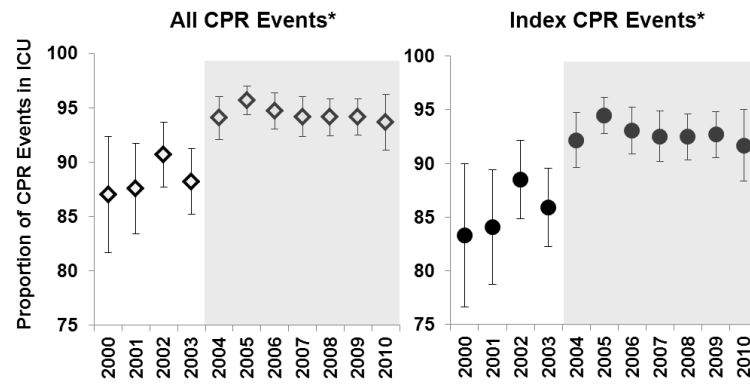


Figure 2.

Proportion of in-hospital CPR events occurring in an ICU vs. general ward. *Over time, significantly more events occurred in the ICU compared to the general wards (test for trend: $p < 0.01$). A prominent shift in location was noted between 2003 and 2004 (2000 – 003: 87 – 91% vs. 2004 – 2010: 94 – 96%)

Table 1

Unadjusted survival outcomes.

	Total	ICU		P	Ward		P
		2000-03	2004-10		2000-03	2004-10	
Age Category, n (%)							
ROSC *	4234 / 5870 (72)	714 / 1059 (67)	3243 / 4418 (73)	<0.01	86 / 135 (64)	191 / 258 (74)	0.033
24 hour survival *	3260 / 5789 (56)	556 / 1042 (53)	2490 / 4373 (57)	0.036	58 / 123 (47)	156 / 251 (62)	<0.01
Survival to hospital discharge †	1735 / 4435 (39)	291 / 814 (36)	1266 / 3241 (39)	0.082	57 / 132 (43)	121 / 248 (49)	0.30
Survival with favorable neurological outcome †	1193 / 1259 (95)	209 / 225 (93)	860 / 899 (96)	0.085	35 / 40 (88)	89 / 95 (94)	0.30

* All CPR events.

† Index CPR events only.

Table 2

Estimated relative risks by modified Poisson regression for survival, 2004-2010 versus 2000-2003 *adjusted for within-center variability, hospital characteristics and baseline factors associated with outcome. The first three models were controlled for hospital characteristics and pre-arrest factors showing at least a trend ($p < 0.15$) towards association on univariate analysis. Due to a small number of patients discharged alive with unfavorable outcomes among survivors, the fourth model was adjusted only for hospital characteristics and pre-arrest factors showing a significant ($p < 0.05$) association with outcome.

	ESTIMATED RELATIVE RISK* 2004-2010 vs. 2000-2003 (CI⁹⁵)
ROSC [†]	1.08 (1.03-1.13)
24 hour survival [†]	1.05 (0.99-1.12)
Survival to hospital discharge [‡]	1.02 (0.91-1.14)
Favorable Neurological Outcome among Survivors [‡]	1.035 (1.005-1.07)

[†] All CPR events.

[‡] Index CPR events only.