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Pediatric In-Hospital Acute Respiratory Compromise: A Report from the American Heart Association's Get With The Guidelines-Resuscitation Registry

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Abstract

Objectives—The main objectives of this study were to describe in-hospital acute respiratory compromise among children (age < 18 years), and its association with cardiac arrest and in-hospital mortality.

Design—Observational study using prospectively collected data.

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Setting—United States hospitals reporting data to the *Get With The Guidelines® – Resuscitation* registry.

Patients—Pediatric patients (age < 18 years) with acute respiratory compromise. Acute respiratory compromise was defined as absent, agonal, or inadequate respiration that required emergency assisted ventilation and elicited a hospital-wide or unit-based emergency response.

Interventions—None.

Measurements and Main Results—The primary outcome was in-hospital mortality. Cardiac arrest during the event was a secondary outcome. To assess the association between patient, event, and hospital characteristics and the outcomes, we created multivariable logistic regressions models accounting for within-hospital clustering. One thousand nine hundred and fifty two patients from 151 hospitals were included. Forty percent of the events occurred on the wards, 19% in the emergency department, 25% in the intensive care unit, and 16% in other locations. Two hundred eighty patients (14.6%) died before hospital discharge. Pre-existing hypotension (odds ratio: 3.26 [95%CI: 1.89, 5.62], $p < 0.001$) and septicemia (odds ratio: 2.46 [95%CI: 1.52, 3.97], $p < 0.001$) were associated with increased mortality. The acute respiratory compromise event was temporally associated with a cardiac arrest in 182 patients (9.3%), among whom 46.2% died. One thousand two hundred and eight patients (62%) required tracheal intubation during the event. In-hospital mortality among patients requiring tracheal intubation during the event was 18.6%.

Conclusion—In this large, multicenter study of acute respiratory compromise, 40% occurred in ward settings, 9.3% had an associated cardiac arrest, and overall in-hospital mortality was 14.6%. Pre-event hypotension and septicemia were associated with increased mortality rate.

Keywords

Intubation; pulmonary ventilation; heart arrest; epidemiology; hospitals

INTRODUCTION

In-hospital acute respiratory failure requiring assisted ventilation occurs frequently in children irrespective of the criteria used to define this condition.(1–7) Even though mortality varies substantially depending on the definitions used(1, 2), mortality may exceed 40% in severe cases.(3, 4) Although there are no published incidence estimates for all pediatric patients, ICD-9-data from a study performed in 2000 estimates the annual incidence at greater than 5,000 cases each year in the United States in children between 5 and 17 years. (5, 8) However, this may represent a substantial underestimation of all pediatric in-hospital acute respiratory failure, because it is particularly common among younger patient groups. (1–4)

Pediatric intubation has been extensively described in the intensive care unit (ICU)(9–16) and emergency department (ED) setting.(17, 18) However, to our knowledge, no large, multi-center study has described the landscape of in-hospital acute respiratory compromise events, defined as absent, agonal, or inadequate respiration requiring emergency assisted ventilation and eliciting a hospital-wide or unit-based emergency response. Likewise, specific data are lacking on children experiencing acute respiratory compromise outside the

ICU or ED setting, although these patients are often included, along with other deteriorating children, in studies of early warning scores and implementation of rapid response teams.(7, 19–24)

This study represents the first report from a large, multicenter, prospective United States registry reporting the epidemiology of pediatric in-hospital acute respiratory compromise across hospital locations for children of all ages. The main objectives were to describe in-hospital acute respiratory compromise events, and assess key patient, event and hospital factors associated with cardiac arrest and in-hospital mortality.

MATERIALS AND METHODS

Study design and data source

This was an observational study using prospectively collected data from the *Get With The Guidelines® – Resuscitation* (GWTG-R) registry.(25) Based in the United States and sponsored by the American Heart Association, the GWTG-R is a quality improvement database of in-hospital cardiac arrest, medical emergency team responses, and acute respiratory compromise events. The registry includes both pediatric and adult patients. Trained personnel at each participating hospital collected data on all of these events according to standard definitions (see below). Certification of data entry personnel and the use of standardized software further improved data integrity.(26, 27) Additional hospital descriptive data were obtained from the American Hospital Association's Annual Survey Database 2013.(28)

All participating hospitals are required to comply with local regulatory guidelines. Because data are used primarily at the local site for quality improvement, sites are granted a waiver of informed consent under the common rule. The Committee on Clinical Investigations at Beth Israel Deaconess Medical Center, Boston, USA confirmed that this is not considered human subjects research under the common law and therefor waived the need for informed consent.

Population and outcomes

The GWTG-R registry defines “acute respiratory compromise” as absent, agonal, or inadequate respiration that requires emergency assisted ventilation and elicits a hospital-wide or unit-based emergency response. This includes non-invasive (e.g., mouth-to-mouth, mouth-to-barrier device, bag-valve-mask, continuous positive airway pressure, or bi-level positive airway pressure) and invasive (e.g., endotracheal or tracheostomy tube, laryngeal mask airway) positive pressure ventilation. Elective intubations and out-of-hospital events are not part of the database.

For this study, we included index events in pediatric patients (age < 18 years) from January 2005 to December 2014. Events were excluded if they occurred in visitors, in the delivery room, newborn nursery, or in neonatal intensive care unit. Patients were also excluded if they had an invasive airway in place or received assisted ventilation immediately prior to the hospital-wide or unit-based emergency response activation. Finally, we excluded events if outcome data was missing, specifically data on cardiac arrest or in-hospital mortality.

The primary outcome was in-hospital mortality. Cardiac arrest during the acute respiratory compromise event was a secondary outcome.

Statistical analyses

We used descriptive statistics to summarize the study population. Survivors and non-survivors were first compared using unadjusted logistic regression. For categorical variables with more than two categories, the category with the largest sample size was chosen as the reference group. Next, we created a multivariable logistic regression model. We used generalized estimation equations with an exchangeable variance-covariance structure to account for correlation among patients within the same hospital. To avoid overfitting, we only included variables in the multivariable model that were different between survivors and non-survivors at a p-value < 0.10 in unadjusted analysis. We then performed backwards selection removing variables one-by-one according to the highest p-value until all variables were associated with the outcome at a p-value < 0.05. In the main multivariable analysis, we only included patients with no missing data.

We considered the following variables for entry into the model (see Table 1 for additional details): age, sex, illness category, pre-existing conditions (see eTable 1 in the supplemental material for definitions), location, time (time of day, day of week, year), whether the event was monitored (ECG, apnea monitor, apnea/bradycardia monitor, and/or pulse oximetry), whether a hospital-wide response was activated (as compared to a unit-wide response), the presence of vascular access, supplemental oxygen at the time of the event, the electrocardiographic rhythm, the breathing pattern and the patient's consciousness at the beginning of the event. We also included hospital-level variables: type of hospital, number of beds, and teaching status. All variables were chosen *a priori* by the author team. We repeated the analysis for the secondary outcome cardiac arrest during the event. Results from the multivariable models are presented as odds ratios (OR) with 95% confidence intervals (95% CI). A predefined subgroup analysis was conducted in those who underwent tracheal intubation during the event.

To account for missing data for included variables, we performed multiple imputations as a sensitivity analysis for the primary outcome in-hospital mortality. Missing values were imputed using the fully conditional specification method.(29) A total of 10 data sets were created. Analyses were then repeated taking into account the imputation.

All hypothesis tests were two-sided with a significance level of $p < 0.05$. No adjustments were made for multiple comparisons; therefore nominal significant p-values should be interpreted with caution. We conducted all statistical analyses with SAS software, version 9.4 (SAS Institute, Cary, NC, USA).

RESULTS

Patient inclusion, missing data, and characteristics

Four thousand five hundred and sixty pediatric acute respiratory compromise events were entered in the GWTG-R registry between January 2005 and December 2014 although the majority of hospitals reported cases for a shorter time period. For the current study, 1952

patients from 151 hospitals met all inclusion criteria and no exclusion criteria (Figure 1). Data was complete for all variables on 905 patients (46%) and 1657 patients (85%) had missing data on two or less variables. The median number of missing values was 1 (quartiles: 0, 1). Additional details on data missingness are provided in the eTable 2 (supplemental material).

Patient, event, and hospital characteristics are provided in Table 1 for both the non-imputed and imputed cohort. All age groups were represented and 45% were female. Forty percent of the events occurred on the wards, 19% in the emergency department, 25% in the intensive care unit, and 16% in other locations. Eighty percent of patients were monitored at the time of the acute respiratory compromise events; 76% with pulse oximetry, 67% with ECG, 14% with apnea monitor, and 20% with apnea/bradycardia monitor. The most common illness category was medical non-cardiac (56%) and the most common pre-existing conditions were non-cardiac congenital malformations (13%), acute non-stroke neurological events (14%), and pneumonia (8%). The majority of patients were spontaneously breathing (61%) and had a sinus rhythm (76%) at the beginning of the event. Patients were included from both primarily adult (51%) and pediatric (49%) hospitals with the majority of the hospitals being major teaching hospitals (69%). For 537 patients (28%) the event ended with unassisted return of spontaneous ventilation (i.e. spontaneous ventilation sustained for > 20 minutes).

Documented interventions during the acute respiratory compromise event are provided in Table 2. One thousand seven hundred and ten patients (88%) received bag-valve mask ventilation during the event, 1208 patients (62%) had tracheal intubations, and 288 patients (15%) received continuous or bi-level positive airway pressure ventilation. Other ventilation interventions were uncommon. The most common pharmacological interventions were administration of sedation/anesthetic agents (46%), neuromuscular blockade (34%), and an intravenous fluid bolus (22%).

In-hospital mortality

Overall, 284 patients (14.6% [95%CI: 13.0%, 16.2%]) died before hospital discharge. Mortality according to year is presented in Figure 2 and according to location in eTable 3 (supplemental material). Patient, event, and hospital characteristics according to mortality is provided in Table 3 for the non-imputed cohort and in eTable 4 (supplemental material) for the imputed cohort.

The results from the multivariable model for in-hospital mortality are presented in Table 4 for both the non-imputed and imputed cohort. The results were largely similar in the two cohorts. Compared to a medical non-cardiac illness category, a medical cardiac illness category was associated with increased mortality (OR: 2.86 [95%CI: 1.73, 4.71]). Pre-existing hypotension (OR: 3.26 [95%CI: 1.89, 5.62]) and septicemia (OR: 2.46 [95%CI: 1.52, 3.97]) were strongly associated with increased mortality. Events at non-teaching (OR: 0.28 [95%CI: 0.12, 0.65]) and minor teaching hospitals (OR: 0.43 [95%CI: 0.20, 0.90]) were associated with decreased mortality as compared to major teaching hospitals.

Cardiac arrest during the event

The acute respiratory compromise event was temporally associated with a cardiac arrest in 182 patients (9.3% [95%CI: 8.1%, 10.7%]). For these patients, the in-hospital mortality was 46.2% (95%CI: 38.8%, 53.7%) compared to 11.3% (95%CI: 9.9%, 12.9%) in those without an acute respiratory compromise-associated cardiac arrest ($p < 0.001$). The proportion of patients with a cardiac arrest during the event per year is provided in Figure 2 and according to location in eTable 3 (supplemental material). The median time to cardiac arrest from the beginning of the event was 7 minutes (quartiles: 3, 16), see eFigure 1 in the supplemental material. This information was missing on 9% of the patients.

The results of the univariate analyses regarding cardiac arrest during the event are presented in eTable 5 (supplemental material) and the results of the multivariable analysis are presented in Table 5. Neonates and patients with an acute non-stroke neurological event had decreased odds of cardiac arrest during the event. Having an event on an inpatient floor, compared to an ICU, ED or other location was also associated with decreased odds of cardiac arrest.

Intubated subgroup

One thousand two hundred and eight patients (62%) required tracheal intubation during the event. In-hospital mortality in this patient population was 18.6% (95%CI: 16.5%, 20.9%). One hundred thirty four of these 1208 patients (11.1% [95%CI: 9.4%, 13.0%]) had a cardiac arrest and these patients had an overall in-hospital mortality of 51.5% (95%CI: 39.8%, 57.3%). Characteristics according to mortality is presented in eTable 6 (supplemental material) and the results of the multivariable model are presented in eTable 7 (supplemental material). The results in this subgroup were largely similar to the full cohort. Medical cardiac illness category, pre-existing hypotension, and septicemia were strongly associated with increased mortality.

DISCUSSION

In this multicenter study of children having an acute respiratory compromise event that required emergency assisted ventilation and elicited a hospital-wide or unit-based emergency response, we found an overall mortality of approximately 15%. Forty percent occurred in a ward setting, 28% had unassisted return of spontaneous ventilation during the event, and 9% had an acute respiratory compromise-associated cardiac arrest. Patients with cardiac arrests had a much higher mortality rate of 46%. Medical cardiac illness category, pre-existing hypotension and septicemia were patient characteristics consistently and strongly associated with increased mortality, even when other potentially confounding patient, event and hospital factors were accounted for.

Among these 1951 children with acute respiratory compromise events, 28% of the events ended with unassisted return of spontaneous ventilation. Presumably, some of these events were due to acute reversible neurologic events (e.g., seizures, responses to medications) and some were due to reversible obstructive and/or central apnea. In contrast, 88% were treated

with bag-valve-mask ventilation, 62% had tracheal intubations, and 15% received continuous or bi-level positive airway pressure ventilation.

The National Emergency Airway Registry for Children (“NEAR4KIDS”) has provided valuable information on the occurrence of adverse events from emergent and non-emergent tracheal intubation in the ICU setting.(9–16) In the pediatric ICU setting, severe adverse events occurred in approximately 6% of cases and less than 2% of patients progressed to cardiac arrest during the event.(11, 14) Similar, or slightly higher, cardiac arrest event rates have been described in the ED for pediatric(18) and adult(30, 31) patients in relation to emergency intubation. These estimates are lower than the 9.3% reported here. However, there are important differences in the included patient population that limits direct comparison. Specifically, the inclusion criteria for the acute respiratory compromise GWTG-R registry includes activation of a unit- or hospital-wide response during the event likely selecting a more acutely ill patient population for inclusion. The ICU mortality from the NEAR4KIDS registry is approximately 12%(12), which is more aligned with the in-hospital mortality rate of 15% we report here.

A number of patient characteristics were consistently associated with mortality in the primary analysis, the sensitivity analysis accounting for missing data, and in the subgroup of patients who received tracheal intubation during the event: medical cardiac illness category, pre-existing hypotension, and septicemia. The fact that hemodynamic instability (i.e. hypotension and septicemia) was associated with increased mortality is perhaps expected yet important. Nishisaki et al., using the NEAR4KIDS registry, found that a diagnostic category of sepsis/shock and unstable hemodynamics prior to the event were associated with increased risk of severe adverse events.(11) In adults, pre-event hemodynamic instability has been associated with cardiac arrest and/or in-hospital mortality in a number of studies in the ED, ICU, and on inpatient wards.(27, 31–33) Furthermore, hemodynamic instability is a predictor of mortality in pediatric patients with acute respiratory failure receiving mechanical ventilation.(2) Whether hemodynamic optimization before/during airway management could lead to improved outcomes remains to be determined. We also found that hospital characteristics such as non-teaching and minor teaching hospitals were associated with decreased mortality in the multivariable model. Although the reasons for these findings are unknown, we speculate that patients in major teaching hospitals are different and might constitute a generally sicker patient population.

A previous study from the GWTG-R registry found that survival has increased over the last decade for in-hospital pediatric cardiac arrest.(34) In the current study, we found a similar significant trend with decreasing mortality from 2005 (19%) to 2014 (12%) after acute respiratory compromise. This remained significant in multivariable analysis indicating that the decrease in mortality cannot be explained by temporal changes in patient characteristics as captured in the GWTG-R registry. This finding did not remain significant in our imputed cohort and should therefore be interpreted with caution. However, whether this potential decrease in mortality is driven by improved acute management of the acute respiratory compromise event, by better intensive care management after the event, by changes in uncaptured patient characteristics, or by something else remains to be determined. Notably, we did not find a decrease over time in the number of events progressing to cardiac arrest in

multivariable analysis, perhaps indicating that any changes in mortality (if true) are driven more by post-event care.

This study should be interpreted in the context of the study design and a number of limitations. Although the GWTG-R encourages inclusion of all events meeting all inclusion criteria and none of the exclusion criteria, we cannot guarantee that all eligible events are captured. As such, a selection bias might underestimate the actual incidence of acute respiratory compromise, but overestimate the incidence of acute respiratory compromise-associated cardiac arrest and mortality. Our analysis of outcomes over time is limited by the fact that hospitals participated in the registry for varying time periods. The sample size did not allow us to examine trends over time within individual hospitals. While the overall proportion of missing data was relatively low (median 1 [quartiles: 0, 1] out of 30 variables included), the proportion of missing data on a few specific variables (e.g., the rhythm at start of event and the level of consciousness) were relatively high. We tried to account for this by multiple imputation and these analyses gave largely similar results and conclusions. While this was a large multicenter study, the number of events was relatively low especially for the secondary outcome of cardiac arrest; therefore the multivariable model for this outcome should be interpreted with caution. Lastly, we were limited by the data and the data definitions included in the GWTG-R registry. For example, the definition of “septicemia” in the current study is different from prior and current definitions of sepsis. We were also unable to determine the specific cause of some of the pre-existing conditions such as “acute non-stroke neurological event” and the reasons for choice of ventilation or drugs given.

CONCLUSION

This is the first study from the GWTG-R registry describing acute respiratory compromise (i.e. absent, agonal, or inadequate respiration that requires emergency assisted ventilation) and elicits a hospital-wide or unit-based emergency response. We found that 40% occurred in ward settings, 28% had unassisted return of spontaneous ventilation during the event, and 9.3% progressed to cardiac arrest with a median time to cardiac arrest of 7 minutes. In-hospital mortality was 14.6%. Several patient and acute respiratory compromise event characteristics were consistently associated with mortality even after accounting for other potentially confounding patient, event, and hospital factors: an unmonitored event, medical cardiac illness category, pre-existing hypotension, and septicemia.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Patient inclusion/exclusion

Of 4590 acute respiratory compromise (ARC) events in the registry, 1952 were included in this study. 284 (14.6%) died before hospital discharge.

Figure 2. Outcomes over time

Proportion of patients dying (black circles) and progressing to cardiac arrest (grey squares) according to the year of the event. Error bars represent exact 95% confidence intervals.

There was a significant unadjusted decreased in in-hospital mortality over time (OR per year 0.92 [95% CI: 0.88, 0.96]) that remained significant in multivariable analysis in the non-imputed cohort but not in the imputed cohort.

Table 1Patient, event, and hospital characteristics^{a,b}

Characteristics	Main cohort ^c (n = 1952)	Cohort with imputed values ^d (n = 1952)
Demographics		
Age		
Neonate (< 1 month)	470 (24)	470 (24)
Infant (1 month up to 1 year)	469 (24)	469 (24)
Child (1 year to 12 year)	712 (36)	712 (36)
Adolescent (> 12 years)	301 (15)	301 (15)
Sex		
Male	1070 (55)	1070 (55)
female	882 (45)	882 (45)
Illness category		
Medical cardiac	164 (8)	164 (8)
Medical non-cardiac	1096 (56)	1101 (56)
Surgical cardiac	136 (7)	136 (7)
Surgical non-cardiac ^e	330 (17)	332 (17)
Newborn ^f	219 (11)	219 (11)
Pre-existing conditions^g		
Cyanotic cardiac malformation	124 (7)	146 (7)
Acyanotic cardiac malformation	86 (5)	96 (5)
Non-cardiac congenital malformation	215 (13)	236 (12)
CHF this admission	54 (3)	61 (3)
Hypotension	112 (7)	128 (7)
Acute stroke	13 (1)	18 (1)
Acute non-stroke neurological event	244 (14)	276 (14)
Pneumonia	142 (8)	157 (8)
Septicemia	126 (7)	146 (7)
Major trauma	111 (7)	121 (6)
None of the above	721 (42)	845 (43)
Location of the event		
Emergency department	368 (19)	368 (19)
Floor with telemetry/step-down unit	134 (7)	134 (7)
Floor without telemetry	653 (33)	653 (33)
Intensive care unit	493 (25)	493 (25)
OR/PACU/procedural area	175 (9)	175 (9)
Other	129 (7)	129 (7)
Time of the event		
Year		
2005 – 2006	430 (22)	430 (22)
2007 – 2008	339 (17)	339 (17)

Characteristics	Main cohort ^c (n = 1952)	Cohort with imputed values ^d (n = 1952)
2009 – 2010	473 (24)	473 (24)
2011 – 2012	403 (21)	403 (21)
2013 – 2014	307 (16)	307 (16)
Time of week		
Weekday (Monday – Friday)	1461 (76)	1461 (76)
Weekend (Saturday – Sunday)	435 (24)	435 (24)
Time of day		
Day (7:00 am – 10:59 pm)	1410 (76)	1489 (76)
Night (11:00 pm – 6:59 am)	435 (24)	463 (24)
Event characteristics		
Monitored	1562 (80)	1563 (80)
Hospital wide response activated	1057 (54)	1057 (54)
Vascular access in place	1396 (72)	1396 (72)
Supplemental oxygen in place	922 (52)	1018 (52)
Rhythm at start of event		
Bradycardia	298 (21)	436 (22)
Sinus (including sinus tachycardia)	1065 (76)	1467 (75)
Other	34 (2)	50 (3)
Breathing pattern		
Breathing	1125 (61)	1186 (61)
Not breathing	481 (26)	517 (26)
Agonal	233 (13)	250 (13)
Patient conscious	993 (63)	1225 (63)
Hospital characteristics		
Hospital type		
Primarily adult	991 (52)	1004 (51)
Primarily pediatric	930 (48)	948 (49)
Number of beds		
< 250	206 (11)	208 (11)
250 – 499	1046 (54)	1064 (54)
500	669 (35)	680 (35)
Teaching status		
Non-teaching	183 (10)	184 (9)
Minor teaching	418 (22)	425 (22)
Major teaching	1318 (67)	1342 (69)

^a CHF denotes chronic heart failure, OR operating room, PACU post-anesthesia care unit

^b All variables are reported as counts (frequencies)

^c Percentages indicate relative frequencies with non-missing values as the denominator

^d Values reflect “averaged” values over the 10 imputed data sets

^e Includes trauma and obstetric patients

^fI.e. being born on the current admission

^gSee eTable 1 in the supplemental material for definitions

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Table 2Documented resuscitation interventions^{a,b}

Characteristics	All patients (n = 1951)
Type of ventilation	
Bag-valve mask	1710 (88)
Endotracheal tube	1208 (62)
CPAP/BiPAP	288 (15)
Other non-invasive ventilation	46 (2)
Tracheostomy	18 (1)
Laryngeal mask	11 (1)
Mouth to barrier device	9 (0)
Mouth to mouth	3 (0)
Drugs given	
Sedation/Induction	906 (46)
Neuromuscular blockade	664 (34)
Intravenous fluid bolus	432 (22)
Sodium bicarbonate	101 (5)
Reversal agent	83 (4)
Calcium chloride/gluconate	49 (3)
Dextrose	29 (1)
Bronchodilator	18 (1)
Magnesium sulfate	12 (1)
Prostaglandins	4 (0)
Other	517 (27)
None	613 (31)

^a Data was missing on one person. Variables were collected as “yes” vs. “no/not documented”

^b CPAP: continuous positive airway pressure, BiPAP: biphasic positive airway pressure

Table 3Unadjusted comparison between survivors and non-survivors^a

Characteristics	Non-survivors ^b (n = 284)	Survivors ^b (n = 1668)	Odds ratio ^c (95%CI)	p-value
Demographics				
Age				
Neonate (< 1 month)	56 (20)	414 (25)	0.91 (0.64, 1.30)	0.61
Infant (1 month up to 1 year)	79 (28)	390 (23)	1.37 (0.99, 1.89)	0.06
Child (1 year to 12 year)	92 (32)	620 (37)	Reference	–
Adolescent (> 12 years)	57 (20)	244 (15)	1.57 (1.10, 2.26)	0.01
Sex				
Male	144 (51)	926 (56)	Reference	–
female	140 (49)	742 (44)	1.21 (0.94, 1.56)	0.13
Illness category				
Medical cardiac	47 (17)	117 (7)	2.57 (1.76, 3.76)	< 0.001
Medical non-cardiac	148 (52)	948 (57)	Reference	–
Surgical cardiac	27 (10)	109 (7)	1.59 (1.01, 2.50)	0.05
Surgical non-cardiac	35 (12)	295 (18)	0.76 (0.51, 1.12)	0.17
Newborn	26 (9)	193 (12)	0.86 (0.55, 1.35)	0.52
Pre-existing conditions				
Cyanotic cardiac malformation	31 (13)	93 (6)	2.21 (1.44, 3.41)	< 0.001
Acyanotic cardiac malformation	15 (6)	71 (5)	1.32 (0.75, 2.35)	0.34
Non-cardiac congenital malformation	34 (14)	181 (12)	1.18 (0.80, 1.76)	0.40
CHF this admission	13 (5)	41 (3)	2.01 (1.06, 3.81)	0.03
Hypotension	46 (19)	66 (5)	5.09 (3.39, 7.63)	< 0.001
Acute stroke	1 (0)	12 (1)	0.51 (0.07, 3.95)	0.52
Acute non-stroke neurological event	24 (10)	220 (15)	0.64 (0.41, 0.99)	0.05
Pneumonia	23 (10)	119 (8)	1.21 (0.76, 1.94)	0.42
Septicemia	38 (16)	88 (6)	2.98 (1.98, 4.48)	< 0.001
Major trauma	13 (5)	98 (7)	0.81 (0.45, 1.46)	0.48
None of the above	66 (28)	655 (45)	0.48 (0.35, 0.64)	< 0.001
Location of the event				
Emergency department	44 (15)	324 (19)	1.10 (0.74, 1.63)	0.65
Floor with telemetry/step-down unit	19 (7)	115 (7)	1.33 (0.77, 2.30)	0.30
Floor without telemetry	72 (25)	581 (35)	Reference	–
Intensive care unit	117 (41)	376 (23)	2.51 (1.82, 3.46)	< 0.001
OR/PACU/procedural area	14 (5)	161 (10)	0.70 (0.39, 1.28)	0.25
Other	18 (6)	11 (7)	1.31 (0.75, 2.28)	0.34
Time of the event				
Year			0.92 ^d (0.88, 0.96)	< 0.001
2005 – 2006	74 (26)	356 (21)		
2007 – 2008	61 (21)	278 (17)		
2009 – 2010	70 (25)	403 (24)		

Characteristics	Non-survivors ^b (n = 284)	Survivors ^b (n = 1668)	Odds ratio ^c (95%CI)	p-value
2011 – 2012	51 (18)	352 (21)		
2013 – 2014	28 (10)	279 (17)		
Time of week				
Weekday (Monday – Friday)	220 (77)	1241 (74)	Reference	–
Weekend (Saturday – Sunday)	64 (23)	427 (26)	0.85 (0.63, 1.14)	0.27
Time of day				
Day (7:00am – 10:59 pm)	192 (72)	1218 (77)	Reference	–
Night (11pm – 6:59am)	75 (28)	360 (23)	1.32 (0.99, 1.77)	0.06
Event characteristics				
Monitored	241 (85)	1321 (79)	1.46 (1.03, 2.06)	0.03
Hospital wide response activated	121 (43)	936 (56)	0.58 (0.45, 0.75)	< 0.001
Vascular access in place	214 (75)	1182 (71)	1.25 (0.94, 1.67)	0.13
Supplemental oxygen in place	163 (63)	759 (51)	1.64 (1.25, 2.15)	< 0.001
Rhythm at start of event				
Bradycardia	64 (29)	234 (20)	1.70 (1.22, 2.35)	0.002
Sinus (including sinus tachycardia)	148 (67)	917 (78)	Reference	–
Other	9 (4)	25 (2)	2.23 (1.02, 4.87)	0.04
Breathing pattern				
Breathing	148 (57)	977 (62)	Reference	–
Not breathing	65 (25)	416 (26)	1.03 (0.75, 1.41)	0.85
Agonal	47 (18)	186 (12)	1.67 (1.16, 2.40)	0.006
Patient conscious	131 (57)	862 (64)	0.76 (0.57, 1.01)	0.06
Hospital characteristics				
Hospital type				
Primarily adult	139 (50)	852 (52)	Reference	–
Primarily pediatric	138 (50)	791 (48)	1.08 (0.84, 1.39)	0.57
Number of beds				
< 250	15 (5)	191 (12)	0.48 (0.27, 0.83)	0.009
250 – 499	148 (53)	898 (55)	Reference	–
500	115 (41)	554 (34)	1.26 (0.97, 1.64)	0.09
Teaching status				
Non-teaching	12 (4)	171 (10)	0.35(0.19, 0.65)	< 0.001
Minor teaching	47 (17)	371 (23)	0.64 (0.46, 0.90)	0.009
Major teaching	218 (79)	1100 (67)	Reference	–

^a CHF denotes chronic heart failure, OR operating room, PACU post-anesthesia care unit

^b All variables are reported as counts (frequencies)

^c Odds ratio for in-hospital mortality

^d Odds ratio per year

Table 4

Multivariable model for mortality

Characteristics	Non-imputed cohort (n = 905)		Imputed cohort (n = 1952)	
	Odds ratio (95%CI)	p-value	Odds ratio (95%CI)	p-value
Illness category				
Medical cardiac	2.86 (1.73, 4.71)	< 0.001	2.20 (1.47, 3.30)	< 0.001
Medical non-cardiac	Reference	–	Reference	–
Surgical cardiac	1.68 (0.90, 3.15)	0.11	1.23 (0.83, 1.81)	0.30
Surgical non-cardiac	0.69 (0.37, 1.28)	0.24	0.78 (0.52, 1.17)	0.23
Newborn	1.43 (0.67, 3.07)	0.35	1.15 (0.61, 2.16)	0.67
Pre-existing conditions				
Hypotension	3.26 (1.89, 5.62)	< 0.001	3.92 (2.73, 5.63)	< 0.001
Septicemia	2.46 (1.52, 3.97)	< 0.001	2.53 (1.61, 3.98)	< 0.001
Time of the event				
Year per year	0.92 (0.85, 1.00)	0.04	–	–
Event characteristics				
Monitored	0.51 (0.30, 0.87)	0.01	–	–
Hospital wide response activated	0.42 (0.27, 0.67)	< 0.001	0.63 (0.43, 0.92)	0.02
Supplemental oxygen in place	1.93 (1.14, 3.27)	0.01	1.57 (1.14, 2.17)	0.006
Breathing pattern				
Breathing	Reference	–	Reference	–
Not breathing	1.59 (0.99, 2.54)	0.05	1.43 (1.01, 2.02)	0.04
Agonal	2.94 (1.67, 5.18)	< 0.001	2.05 (1.26, 3.34)	0.004
Hospital characteristics				
Teaching status				
Non-teaching	0.28 (0.12, 0.65)	0.003	0.30 (0.15, 0.59)	< 0.001
Minor teaching	0.43 (0.20, 0.90)	0.03	0.57 (0.36, 0.92)	0.02
Major teaching	Reference	–	Reference	–

Table 5

Multivariable model for cardiac arrest (n = 905)

Characteristics	Odds ratio (95%CI)	p-value
Demographics		
Age		
Neonate (< 1 month)	0.36 (0.16, 0.82)	0.01
Infant (1 month up to 1 year)	0.99 (0.60, 1.65)	0.98
Child (1 year to 12 year)	Reference	–
Adolescent (> 12 years)	0.73 (0.33, 1.63)	0.44
Pre-existing conditions		
Acute non-stroke neurological event	0.41 (0.18, 0.92)	0.03
Location of the event		
Emergency department	6.31 (2.21, 18.0)	< 0.001
Floor with telemetry/step-down unit	0.87 (0.17, 4.39)	0.86
Floor without telemetry	Reference	–
Intensive care unit	4.93 (2.02, 12.1)	< 0.001
OR/PACU/procedural area	7.19 (2.08, 24.9)	0.002
Other	3.06 (0.85, 11.1)	0.09
Event characteristics		
Rhythm at start of event		
Bradycardia	3.05 (1.69, 5.48)	< 0.001
Sinus (including sinus tachycardia)	Reference	–
Other	1.30 (0.25, 6.88)	0.76
Breathing pattern		
Breathing	Reference	–
Not breathing	2.43 (1.28, 4.63)	0.007
Agonal	2.73 (1.15, 6.45)	0.02
Hospital characteristics		
Teaching status		
Non-teaching	0.16 (0.03, 0.78)	0.02
Minor teaching	0.75 (0.34, 1.69)	0.49
Major teaching	Reference	–