Hospital-wide Code Rates and Mortality Before and After Implementation of a Rapid Response Team

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Context Rapid response teams have been shown in adult inpatients to decrease cardiopulmonary arrest (code) rates outside of the intensive care unit (ICU). Because a primary action of rapid response teams is to transfer patients to the ICU, their ability to reduce hospital-wide code rates and mortality remains unknown.

Objective To determine rates of hospital-wide codes and mortality before and after implementation of a long-term rapid response team intervention.

Design, Setting, and Patients A prospective cohort design of adult inpatients admitted between January 1, 2004, and August 31, 2007, at Saint Luke's Hospital, a 404-bed tertiary care academic hospital in Kansas City, Missouri. Rapid response team education and program rollout occurred from September 1 to December 31, 2005. A total of 24 193 patient admissions were evaluated prior to the intervention (January 1, 2004, to August 31, 2005), and 24 978 admissions were evaluated after the intervention (January 1, 2006, to August 31, 2007).

Intervention Using standard activation criteria, a 3-member rapid response team composed of experienced ICU staff and a respiratory therapist performed the evaluation, treatment, and triage of inpatients with evidence of acute physiological decline.

Main Outcome Measures Hospital-wide code rates and mortality, adjusted for preintervention trends.

Results There were a total of 376 rapid response team activations. After rapid response team implementation, mean hospital-wide code rates decreased from 11.2 to 7.5 per 1000 admissions. This was not associated with a reduction in the primary end point of hospital-wide code rates (adjusted odds ratio [AOR], 0.76 [95% confidence interval {CI}, 0.57-1.01]; $P=.06$), although lower rates of non-ICU codes were observed (non-ICU AOR, 0.59 [95% CI, 0.40-0.89] vs ICU AOR, 0.95 [95% CI, 0.64-1.43]; $P=.03$ for interaction). Similarly, hospital-wide mortality did not differ between the preintervention and postintervention periods (3.22 vs 3.09 per 100 admissions; AOR, 0.95 [95% CI, 0.81-1.11]; $P=.52$). Secondary analyses revealed few instances of rapid response team undertreatment or underuse that may have affected the mortality findings.

Conclusion In this large single-institution study, rapid response team implementation was not associated with reductions in hospital-wide code rates or mortality.

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In-hospital cardiac arrests are common[1,2] and delays in treatment are associated with lower survival and worse neurological outcomes.[1] Prior studies have reported that adult patients often exhibit physiological deterioration hours before cardiopulmonary arrest.[3-5] As a result, the Institute for Healthcare Improvement recommended in their 100 000 Lives Campaign that hospitals implement rapid response teams as 1 of 6 strategies to reduce preventable in-hospital deaths.[6] In response, hundreds of hospitals around the country have invested significant financial and personnel resources in implementing rapid response teams, despite the fact that limited published data support their effectiveness.

A rapid response team, also known as a medical emergency team, is a multidisciplinary team of intensive care unit (ICU) personnel charged with the evaluation, triage, and treatment of non-ICU patients with signs of clinical deterioration to reduce the rates of in-hospital cardiopulmonary arrests (codes) and their attendant morbidity and mortality. Several studies have shown that rates of non-ICU codes decrease after rapid response team implementation,[7-11] but these studies, which have focused on cardiopulmonary arrests outside of the ICU, may lead to a favorable bias for rapid response teams

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because cardiac arrests that occurred after transferring patients with physiological decline to the ICU were not included.

To date, no adult studies have described the benefits of rapid response team interventions on overall hospital-wide code rates to control for this potential reporting bias. Moreover, most adult studies of rapid response team implementation have used a preintervention vs a postintervention design with follow-up periods of only several months and therefore may not have adequately adjusted for seasonal variations in disease severity.[11-14] In addition, even when a rapid response team program is in effect, the proportion of cardiopulmonary arrests in which the rapid response team was not activated (representing missed opportunities for prompt intervention) is unknown. Finally, because in-hospital cardiopulmonary arrests are associated with poor survival,[1] whether rapid response team implementation is associated with lower hospital-wide mortality through a reduction of cardiopulmonary arrest rates remains controversial.

To address these important gaps in knowledge, we examined the association between a rapid response team intervention and long-term changes in hospital-wide cardiopulmonary arrest and mortality rates, with further characterization of cardiopulmonary arrest rates by hospital location (non-ICU and ICU). In addition, we assessed rates of potential underuse of rapid response teams by determining the proportion of cardiopulmonary arrests that should have prompted a rapid response team intervention but did not.

METHODS

To determine the association between rapid response team implementation and changes in adult hospital-wide cardiopulmonary arrest rates and mortality, we conducted a prospective cohort study at the main hospital campus of Saint Luke's Health Care System. Saint Luke's Hospital is a 404-bed (365 adult beds) tertiary care hospital located in Kansas City, Missouri, with a full complement of heart, solid organ, and bone marrow transplant services, surgery programs, and medical and surgical subspecialties. The hospital includes 271 medical-surgical beds, 41 obstetrical beds, and 53 ICU beds (12 cardiac, 12 medical, and 29 general surgical, cardiothoracic, and neurosurgical). Between January 1, 2004, and August 31, 2007, detailed patient information for all cardiopulmonary arrests and rapid response team interventions was prospectively collected in a hospital resuscitation database as part of a quality-improvement initiative among the 49 171 adult patients hospitalized at Saint Luke's Hospital. This project was reviewed and approved by the institutional review board at Saint Luke's Hospital, and the requirement for informed consent was waived.

Patients who were aged 18 years or older were included if they were admitted during the study period and spent at least 1 day on an adult ward. The preintervention period was between January 1, 2004, and August 31, 2005, and the postintervention period, defined for identical time duration and seasonality, was between January 1, 2006, and August 31, 2007. Staff education and rapid response team program rollout occurred from September 1 to December 31, 2005, and patient data from this period was excluded. Cardiopulmonary arrests occurring in operating rooms and procedural areas also were excluded from the analysis because the etiology and resuscitation environment of these arrests differ from nonprocedural arrests.

Rapid Response Team Intervention

On January 1, 2006, Saint Luke's Hospital implemented a nurse-led rapid response team composed of 2 experienced ICU nurses and a respiratory therapist to respond to all calls for adult inpatients. An ICU attending or fellow joined the team's evaluation when requested by the rapid response team. Education regarding the rapid response team program had been provided through presentations and reinforced with resource handouts, posters, and stickers to medical and nursing staff in all adult inpatient hospital areas during the 4-month informational and educational period (September to December 2005). Standard criteria were used to activate the rapid response team and included acute changes in the patient's mental status, respiratory rate, heart rate, oxygenation, or blood pressure, and hypoxia, chest pain, or worry from clinical staff.

Rapid response team activation occurred via dedicated pagers through the operator with a single emergency telephone number. When activated, the rapid response team was expected to arrive within 10 minutes, complete patient assessments within 30 minutes, and order diagnostic tests and therapeutic treatments pertinent to the patient's condition. In addition, the rapid response team would discuss management with the patient's primary team and determine the need for more intensive monitoring or establishment of do not resuscitate (DNR) status, when appropriate.

Study Outcomes and Variables

The primary study outcomes were hospital-wide cardiopulmonary arrest rates per 1000 admissions and mortality rates per 100 admissions. A code was defined as any patient with an unexpected cardiac or respiratory arrest requiring resuscitation and activation of a hospital-wide alert. Cardiac arrests were defined as cessation of cardiac mechanical activity, determined by the absence of a palpable central pulse, apnea, and unresponsiveness. Respiratory arrests were defined as apnea and unresponsiveness.

To further explore the association between rapid response team implementation and changes in code rates, code rates also were examined by location (ICU vs non-ICU) and by code type (respiratory arrests, shockable cardiac arrests [pulseless ventricular tachycardia or ventricular fibrillation], and nonshockable cardiac arrests [asystole or pulseless electrical activity]). Finally, the degree to which the rapid re-

Table 1. Demographic Characteristics of Study Population Before and After Rapid Response Team Intervention

	Preintervention[a]		Postintervention[a]		
	2004 (n = 14 287)	2005 (n = 9906)[b]	2006 (n = 14 652)	2007 (n = 10 326)[b]	*P* Value for Trend
Age, mean (SD), y	56.8 (13.6)	56.5 (13.8)	57.0 (13.9)	57.1 (13.8)	.02
Men	5701 (39.9)	4141 (41.8)	6256 (42.7)	4420 (42.8)	<.001
Race					
White, non-Hispanic	11 001 (77.0)	7519 (75.9)	11 048 (75.4)	7579 (73.4)	<.001
White, Hispanic	743 (5.2)	535 (5.4)	733 (5.0)	516 (5.0)	
Black	2086 (14.6)	1565 (15.8)	2505 (17.1)	1962 (19.0)	
Asian	186 (1.3)	119 (1.2)	190 (1.3)	145 (1.4)	
Other[c]	271 (1.9)	158 (1.6)	176 (1.2)	124 (1.2)	
Case-mix index[d]	1.90	1.89	1.92	1.98	<.001
Length of stay, median (IQR), d	3 (2-6)	3 (2-6)	3 (2-6)	3 (2-6)	>.99

Abbreviation: IQR, interquartile range.
[a] Values are expressed as number (percentage) unless otherwise indicated.
[b] Sample size represents follow-up from January through August for that year.
[c] Patients designated themselves as Pacific-Islanders, Native Americans, and of multiple races (ie, the patient did not identify with any of the other discrete categories of race, such as black, Asian, etc).
[d] Measurement of a hospital's average patient illness acuity, based on the US Centers for Medicare & Medicaid Services' cost weights.[15]

sponse team was poorly implemented at the hospital was investigated because of potential rapid response team undertreatment or underuse.

Patients in whom a rapid response team intervention was initiated but who subsequently sustained a code outside of the ICU were designated as treatment failures (rapid response team undertreatment). The charts of all cardiopulmonary arrest patients during the postintervention period also were reviewed to determine the proportion of arrests occurring outside of the ICU in which the patient experienced acute clinical deterioration meeting rapid response team activation criteria of 2 hours or longer and 12 hours or shorter from their code but in whom a rapid response team evaluation was not triggered. These codes were designated as cases of rapid response team underuse.

To account for potential changes of the population during the study period, demographic data on age, sex, and race (as identified by patients or their families) were collected on all admissions for each study year. Hospital case-mix index,[15] a reflection of disease severity at Saint Luke's Hospital, was collected preintervention and postintervention. Data on the primary reason for rapid response team activation, rapid response team interventions, and patient disposition after rapid response team evaluation were prospectively collected in the hospital resuscitation database. Data on codes, including location (ICU vs non-ICU), type of arrest (cardiac vs respiratory), initial rhythm for cardiac arrests, and survival to hospital discharge were similarly collected.

Statistical Analysis

Differences in demographics and case-mix during the 4 years were compared using the Mantel-Haenszel trend test for categorical variables and the linear trend test for continuous variables. Code and mortality rates were determined based on monthly admission volumes.

A quasi-experimental approach was used to assess the association between a rapid response team implementation program and changes in hospital-wide code and mortality rates. Potential autocorrelations between months were assessed prior to construction of regression models, and no evidence of significant autocorrelation was found. Because most prior studies have performed only aggregate preintervention and postintervention comparisons, secular trends in cardiac resuscitation and the effect of ongoing quality-improvement programs by a hospital's code blue committee would not have been accounted for. To adjust for such trends, linear regression models were constructed to examine trends in code rates and mortality rates prior to rapid response team intervention. Next, to ensure that rapid response team postintervention event rates were compared with rates that accounted for even nonsignificant preintervention trends, multivariable random-effects logistic regression models were constructed that used an autoregressive error structure and adjusted for patient demographics and case-mix.

These models then compared the mean postintervention rates with the preintervention regression model event rate of the last preintervention month (which would adjust for ongoing trends prior to the intervention). From this model, the estimated coefficient comparing the preintervention and postintervention periods was interpreted as the effect of the intervention and reported as an odds ratio (OR) with 95% confidence intervals (CIs). Additionally, the effect of the intervention on code rates by hospital location and type of arrest were examined with interaction terms with the rapid response team. As a sensitivity analysis, the association between rapid response team implementation and mortality was assessed if deaths that occurred from potential rapid response team undertreatment and underuse had been prevented. Finally, using Monte Carlo simulation to randomly reclassify postintervention deaths as nondeaths, the threshold number of additional avoidable deaths required for rapid response team implementation to have significantly reduced mortality was determined in this study.

Assuming a 1.1% hospital-wide code rate and 24 200 admissions prior to the intervention, and a 42% reduction in hospital-wide code rate after the intervention (70% reduction in non-ICU codes[7,11] and 60% of all hospital codes being outside the ICU, based on our institution's prior experience), our study would have 99% statistical power to detect, at a 2-sided significance level of .05, a reduction in hospital-wide code rates. Also, assuming a case-fatality rate of 80% for hospital-wide codes[16] and a preintervention hospital-wide mortality rate of 3.22%, this reduction in rates of hospital-wide codes, after adjusting for preintervention trends, would have 78% statistical power to detect, at a 2-sided significance level of .05, a reduction in hospital-wide mortality.

For all analyses, the null hypothesis was evaluated at a 2-sided significance level of .05. All statistical analyses were performed with SAS version 9.1 (SAS Institute, Cary, North Carolina) and R version 2.3.1.

RESULTS

Although numerically small, there were significant differences in the demographic characteristics between the preintervention and the postintervention populations. Patients in the rapid response team postintervention period were older, more likely to be male and of black race, and had higher case-mix estimates (TABLE 1). However, no differences in length of hospital stay (ie, median exposure time to codes) was seen across the study years.

During the 20-month period after intervention implementation, there were a total of 376 rapid response team activations. The most common reasons for rapid response team activation were altered neurological status (27.4%), tachycardia exceeding 130/min (23.4%), tachypnea exceeding 30/min (13.3%), and hypotension assessed as systolic blood pressure lower than 90 mm Hg (11.7%) (TABLE 2). The most common rapid response team interventions taken were electrocardiogram (41.0%), additional peripheral intravenous line access (40.0%), arterial blood gas (32.2%), and chest radiograph (31.1%). After rapid response team activation, patients were transferred to higher-level care in 45.5% of cases: to the ICU (41.2%), telemetry units (3.7%), and procedure or operating suites (0.6%). Those patients who were not transferred had already been on telemetry units for continuous monitoring (51.6%) or had obtained DNR status (2.1%) during the rapid response team intervention.

A total of 70 patients died after rapid response team intervention (18.6%), of which 3 occurred during initial rapid response team response, 43 in the ICU, 12 in non-ICU wards within 1 week after rapid response team intervention, and 12 in non-ICU wards more than 1 week after rapid response team intervention (Table 2). Notably, 51 of these deaths occurred among patients who had DNR status at admission (9 patients; 5 deaths), who obtained DNR status during rapid response team activation (8 patients; 6 deaths), or who subsequently obtained DNR status after rapid response team activation (65 patients; 40 deaths).

Unadjusted hospital-wide code rates per 1000 admissions were 11.20 before rapid response team intervention and 7.53 after rapid response team intervention ($P<.001$), and decreased numerically for all types of code events (TABLE 3). Decreases in non-ICU code rates per 1000 admissions (from 6.08 preintervention to 3.08 postintervention; $P<.001$) accounted for the majority of this difference, with little change in ICU code rates (from 5.13 preintervention to 4.44 postintervention; $P=.27$). Case fatality rates after cardiopulmonary arrest were similar prior to and after the rapid response team intervention (77.9% vs 76.1%, respectively; $P=.65$). In contrast to code rates, unadjusted hospital-wide mortality rates per 100 admissions did not meaningfully change after the rapid response team intervention (3.22 preintervention vs 3.09 postintervention; $P=.41$). Notably, the ratio of deaths to hospital-wide codes increased from 2.88 preintervention to 4.11 postintervention ($P=.001$).

Graphical trends in monthly code rates and mortality rates are depicted in FIGURE 1 and FIGURE 2. Regression models did not reveal a linear trend for either outcome prior to the intervention, although there was a visual trend of a small decrease in code rates over time prior to the rapid response team

Table 2. Reasons, Diagnostic and Treatment Interventions, Patient Disposition, and Deaths Following Rapid Response Team (RRT) Activation

	No. (%) of Activations (n = 376)
Reason for RRT activation	
Altered neurological status	103 (27.4)
Tachycardia (>130/min)	88 (23.4)
Tachypnea (>30/min)	50 (13.3)
Hypotension (systolic blood pressure <90 mm Hg)	44 (11.7)
Hypoxia (oxygen saturation <90%)	30 (8.0)
Staff worried	26 (6.9)
Chest pain	11 (2.9)
Bradycardia (<40/min)	16 (4.3)
Hypopnea (<8/min)	6 (1.6)
Cardiac arrest	0
Other	2 (0.5)
Interventions and procedures implemented by RRT[a]	
Electrocardiogram	154 (41.0)
Additional peripheral intravenous line access	150 (40.0)
Arterial blood gas	121 (32.2)
Chest radiograph	117 (31.1)
Renal and shock laboratory panel	70 (18.6)
Resuscitation fluids	60 (16.0)
Cardiac enzymes	50 (13.3)
Computed tomography scan	47 (12.5)
Noninvasive positive pressure ventilation	41 (10.9)
Intubation	28 (7.4)
Central venous access	28 (7.4)
Intravenous diuretics	27 (7.2)
Intravenous narcan	20 (5.3)
Intravenous nitroglycerin	18 (4.8)
Suctioning	18 (4.8)
Sepsis evaluation with cultures	16 (4.3)
Antiepileptics	14 (3.7)
Inhaled nebulizer treatment	13 (3.5)
Intravenous morphine	12 (3.2)
Intravenous vasopressor	5 (1.3)
Arterial line access	3 (0.8)
Cardioversion	1 (0.3)
Immediate disposition	
Remained on telemetry ward	194 (51.6)
Transferred to adult ICU	155 (41.2)
Transferred to telemetry unit	14 (3.7)
Operating room	1 (0.3)
Cardioversion suite	1 (0.3)
Obtained do not resuscitate status	8 (2.1)
Died	3 (0.8)
Deaths	**(n = 70)**
During RRT response	3 (4.3)
Within ICU	43 (61.4)
Outside ICU	
≤7 d	12 (17.1)
>7 d	12 (17.1)

Abbreviation: ICU, intensive care unit.
[a] All interventions during each RRT response were included.

intervention. After adjusting for this trend and for demographic variables with multivariable models, the rapid response team intervention was not associated with a significant reduction in hospital-wide code rates (adjusted OR, 0.76 [95% CI, 0.57-1.01]; $P = .06$) (TABLE 4), although secondary analyses found that the rapid response team intervention was associated with lower non-ICU code rates (non-ICU wards adjusted OR, 0.59 [95% CI, 0.40-0.89] vs ICU units adjusted OR, 0.95 [95% CI, 0.64-1.43]; $P = .03$ for interaction). Similarly, implementation of a rapid response team was not associated with lower hospital-wide mortality (adjusted OR, 0.95 [95% CI, 0.81-1.11]; $P = .52$).

Potential undertreatment and underuse of the rapid response team intervention also was determined. Of the 24 deaths that occurred after rapid response team intervention in which the patient was not transferred to an ICU and did not obtain DNR status at the time of the intervention, only 2 of these were followed up by a cardiopulmonary arrest code (2 and 18 days after rapid response team intervention) and potentially would be considered as rapid response team undertreatment. Moreover, of the 188 codes in the rapid response team postintervention period, 20 occurred in non-ICU patients who had documented acute physiological decline within 12 hours of the code (10.6%), but where the rapid response team was not activated (potential rapid response team underuse accounting for 16 deaths).

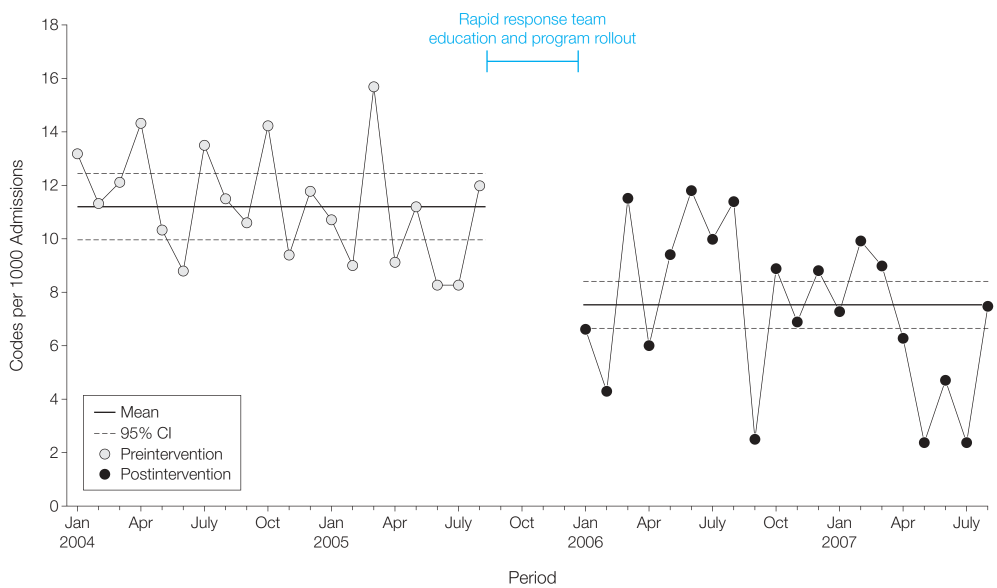
In sensitivity analysis, rapid response team implementation would still have had no significant effect on mortality even if all 18 deaths from these 22 potential cases of rapid response team undertreatment and underuse had been avoided (OR, 0.93 [95% CI, 0.79-1.09]; $P = .35$). In Monte Carlo simulation analysis, rapid response team implementation would need to have prevented an additional 80 deaths in or-

Table 3. Summary of Study Outcomes Before and After Rapid Response Team Implementation

Outcome	No. (Rate per 1000)[a] Preintervention	No. (Rate per 1000)[a] Postintervention	P Value
Hospital-wide admissions	24 193	24 978	
Codes	271 (11.20)	188 (7.53)	<.001
Ventricular fibrillation	62 (2.56)	48 (1.92)	.13
Asystole or pulseless electrical activity	175 (7.23)	122 (4.88)	.001
Respiratory	34 (1.40)	18 (0.72)	.02
Deaths from code, No. (%)[b]	211 (77.9)	143 (76.1)	.65
Hospital bed type			
Intensive care unit	124 (5.13)	111 (4.44)	.27
Non–intensive care unit	147 (6.08)	77 (3.08)	<.001
No. of deaths	780	773	
Mortality rate per 100 admissions	3.22	3.09	.41
Ratio of deaths to hospital-wide codes	2.88	4.11	.001

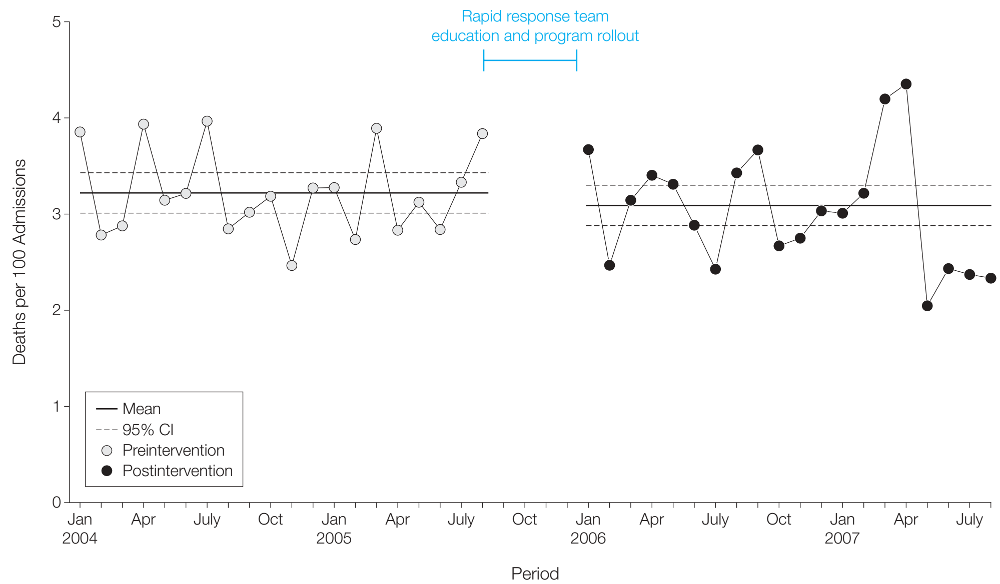
[a] Unless otherwise indicated.
[b] Indicates case fatality rate for codes.

Figure 1. Hospital-Wide Code Rates per 1000 Eligible Adult Patient Admissions by Month



The preintervention period was between January 1, 2004, and August 31, 2005, and the postintervention period was between January 1, 2006, and August 31, 2007. Codes included both respiratory and cardiopulmonary arrests. CI indicates confidence interval.

Figure 2. Hospital-Wide Mortality Rates per 100 Eligible Adult Patient Admissions by Month



The preintervention period was between January 1, 2004, and August 31, 2005, and the postintervention period was between January 1, 2006, and August 31, 2007. CI indicates confidence interval.

der for us to have detected a significant mortality benefit (OR for 693 postintervention deaths, 0.85 [95% CI, 0.72-1.00]).

COMMENT

Our study evaluated the association between rapid response team implementation and both hospital-wide code rates and mortality. To our knowledge, this is the longest follow-up study of a rapid response team intervention with the greatest number of deaths and code events. We found that implementation of a rapid response team was not associated with lower hospital-wide code rates. Similarly, rapid response team intervention was not associated with improvements in the clinically meaningful outcome of hospital-wide mortality. Importantly, only a small percentage of deaths after rapid response team intervention and cardiopulmonary arrests were categorized as potential rapid response team undertreatment or underuse and would not have plausibly altered these findings. We believe that this study provides important new insights regarding the effectiveness and limitations of rapid response team intervention and raises critical questions about whether recommendations to disseminate rapid response teams nationally are warranted without a demonstrable mortality benefit.

Table 4. Model Estimates of the Association Between Rapid Response Team Intervention and Hospital-Wide Code Rates and Mortality

Outcome	Estimate (SE)	Adjusted OR (95% CI)[a]	*P* Value
Hospital-wide codes per 1000 admissions	−0.27 (0.14)	0.76 (0.57-1.01)	.06
Hospital-wide codes per 1000 admissions by arrest type			
Ventricular fibrillation or pulseless ventricular fibrillation	−0.27 (0.28)	0.77 (0.43-1.36)	.36
Asystole or pulseless electrical activity	−0.19 (0.28)	0.82 (0.58-1.18)	.28
Respiratory	−0.70 (0.40)	0.50 (0.22-1.12)	.09
Hospital-wide codes per 1000 admissions by bed type			
Intensive care unit	−0.05 (0.20)	0.95 (0.64-1.43)	.81
Non–intensive care unit	−0.52 (0.20)	0.59 (0.40-0.89)	.01
Mortality rate per 100 admissions	−0.05 (0.08)	0.95 (0.81-1.11)	.52

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Adjusted for demographics, case-mix index, and preintervention trends.

Our work extends the findings of other investigations that have examined the association between rapid response team implementation and code rates and mortality among adult inpatients. Although most prior studies have found that rapid response teams decrease non-ICU code rates,[7-11] the extent to which decreases occurred because early intervention reversed physiological decline or because the rapid response team had simply transferred the patient to the ICU and removed a potential code event from study outcome was unknown. Moreover, follow-up in prior adult studies was often months in duration and did not adjust for seasonal variations in event rates.[11-14] In addition, prior studies of rapid response teams conducted analyses that simply compared aggregate incidence of codes and deaths prior to the rapid response team intervention and after the rapid response team intervention.[9-11,13,14,17,18] This approach does not account for secular trends; therefore, the benefit of rapid response teams on adult inpatients may have been overestimated. This is particularly important when considering the effect of rapid response teams on mortality, in which significant strides in the care of coronary artery disease and heart failure have led to dramatically lower mortality over the past decade.[19,20] With these considerations in mind, we designed a study with long-term postintervention follow-up and identical preintervention and postintervention periods, assessed both hospital-wide code rates and mortality, and adjusted for preintervention secular trends. In performing such a rigorous assessment, we found that implementation of a rapid response team was not associated with lower rates of either hospital-wide codes or mortality.

Limited studies exist on the effect of rapid response team implementation on mortality among adult inpatients, and their results have been mixed and inconclusive,[11,13,18] including conflicting results from 2 short-term randomized trials,[12,21] in which potential contamination in the control group in 1 study was reported (eg, ICU nurses performed informal rapid response team evaluations outside the ICU).[21] We were able to determine in our high-acuity tertiary care hospital, representing a high case-mix, that there were few missed opportunities for rapid response team involvement. Indeed, even if the potential cases of rapid response team undertreatment or underuse were avoidable events, the potential 18 deaths that could have been averted would not have meaningfully changed the association between rapid response team implementation and hospital-wide mortality in this study. These findings underscore the challenges for implementing a successful rapid response team intervention that not only improves intermediate outcomes, such as code rates, but also has downstream effects on hospital-wide mortality.

There are several potential explanations as to why the decrease in non-ICU code rates seen on secondary analyses did not translate into a decrease in the hospital-wide mortality rate. First, although we found that code rates in the ICU were similar between comparison periods (ie, rapid response teams did not just triage sick patients to the ICU who subsequently coded), it is possible that patients who developed cardiopulmonary arrest after rapid response team implementation were more likely to die because rapid response teams may have simply decreased code rates in patients who would have otherwise survived a code without their intervention. However, this is unlikely because we found that case-fatality rates after cardiopulmonary arrest were similar prior to and after the intervention. A second possibility is that patients triaged to the ICU by the rapid response team received clinical care under heightened surveillance. As a result, a sizable proportion of those transferred by the rapid response team may have died in the ICU without formal code activation because these patients were already receiving greater clinical attention.

A third possibility is that a sizable number of patients who survived their initial rapid response team intervention subsequently obtained DNR status during their hospital stay. This is supported by the fact that of the 70 patients who subsequently died after rapid response team intervention, 46 of these deaths occurred among 73 patients who obtained DNR status during or after rapid response team activation. Based on a code case-fatality rate of 78% prior to the rapid response team intervention, this suggests that as many as 59 more hospital-wide codes would have occurred postintervention if these patients had not obtained DNR status. These findings suggest that rapid response teams may not be decreasing code rates as much as catalyzing a compassionate dialogue of end-of-life care among terminally ill patients. This ability to improve end-of-life care may be an important benefit of rapid response teams, particularly given the difficulties in prior trials to increase rates of DNR status among seriously ill inpatients[22] and potential decreases in resource use. Nevertheless, whether the resources and training to establish rapid response teams is the optimal approach to improving end-of-life care is unknown.

Finally, given greater efforts in advanced care planning, it also is possible that a larger proportion of patients in the postintervention period had DNR status at admission. Because we did not prospectively collect data on DNR status for our study population of nearly 50 000 patients, both at hospital admission or established during an admission, we could not discriminate between these possibilities. However, if there was indeed a larger proportion of patients who had DNR status at admission during the postintervention period (which we believe is likely), limiting our analysis to only those patients who did not have DNR status may create a selection bias in favor of a mortality benefit with rapid response team implementation, given that the sickest patients would have preferentially obtained DNR status and would have been excluded from the mortality analyses during the postintervention period.

There are also a variety of outstanding issues with rapid response teams that remain unanswered. First, the composition of rapid response teams is not standardized and varies among hospitals. In our study, the rapid response teams were led by experienced ICU nurses, with physician input when indicated. There did not appear to be evidence of significant rapid response team undertreatment or underuse with a nonphysician-led rapid response team in this study, and comparative studies of nurse-led vs physician-led rapid response teams have not been performed.

The optimal triggers for rapid response team activation also have not been rigorously determined. To date, no study has systematically defined the prevalence or types of physiological parameters that presage in-hospital deaths to assess what key characteristics should trigger rapid response team activation. Moreover, whether automated monitoring of inpatients may be more efficient than rapid response teams in identifying patients with clinical deterioration is unknown. Lastly, the cost-effectiveness of rapid response teams has not been studied. Given our study findings and current gaps in knowledge, more research is needed to establish the overall effectiveness, cost-effectiveness, composition, and optimal implementation of rapid response teams. Hospitals may therefore wish to exercise restraint and invest limited personnel and financial resources into quality-improvement programs with more established efficacy.

Our study should be interpreted in the context of the following limitations. Our study was a cohort study using a historical control. Although we adjusted for temporal trends in code rates and mortality rates prior to the intervention, we may not have fully adjusted for secular trends or other quality-improvement efforts in our hospital that may have influenced study outcomes after the rapid response team intervention. Given the negative findings in our study and steady improvements in quality of care nationally, such adjustments would be unlikely to establish a benefit with rapid response teams. As previously discussed, we did not have data on DNR status for our entire study population, both at hospital admission or established during an admission, which may have limited our ability to detect a mortality benefit.

In addition, our study was slightly underpowered (78% power) to detect a significant mortality difference, but given the estimate of effect and a relatively narrow 95% CI (OR, 0.95 [95% CI, 0.85-1.11]), it is unlikely that our study failed to detect an association between the rapid response team intervention and mortality. In fact, we determined in post hoc power calculations that we would have needed a preintervention and postintervention population of 148 000 patients during each period to have 80% power to detect, at a 2-sided significance level of .05, a 5% reduction in mortality. Lastly, although our study follow-up was one of the longest to date, and although there were more events in this study than in most prior studies, our findings reflect a single institution experience and may not be generalizable to other adult hospitals or rapid response team programs.

CONCLUSION

Implementation of a rapid response team in our tertiary care adult hospital was not associated with lower rates of either hospital-wide cardiopulmonary arrests or mortality. Because of the lack of robust outcomes after the rapid response team intervention, well-designed multicenter adequately powered randomized controlled trials with sufficiently long follow-up should be considered to rigorously evaluate the efficacy of rapid response teams prior to endorsing their widespread implementation.

Author Contributions: Dr Chan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Chan, Spertus.
Acquisition of data: Chan, Khalid, Longmore.
Analysis and interpretation of data: Chan, Khalid, Longmore, Berg, Kosiborod, Spertus.
Drafting of the manuscript: Chan.
Critical revision of the manuscript for important intellectual content: Chan, Khalid, Longmore, Berg, Kosiborod, Spertus.
Statistical analysis: Chan.
Administrative, technical, or material support: Chan, Spertus.
Study supervision: Chan, Khalid, Longmore, Berg, Kosiborod, Spertus.
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