An Evaluation of the Effectiveness and Process Evaluation of a Rapid Response System

Principal Investigator: Tanya Lord

Roger Luckmann, MPH, MD, Thesis Advisor

Terry Field, DSc, Chair of Committee

Robert Klugman, MD, Member of Committee

Patricia Franklin, MD, MPH, MBA, Member of Committee

Sharon Johnson, PhD, Member of Committee

University of Massachusetts Medical School

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ABSTRACT

Purpose: This study evaluated the effectiveness and the implementation of a Rapid Response System (RRS) at the UMass Memorial Medical Center (UMMMC). Additionally, a modified process evaluation was performed to determine how well the intervention worked as designed.

Scope: All adult patients who were admitted to the two study hospitals were included.

Methods: There were two 24-month study periods. A Spline regression model was used to compare the incidence of the three outcomes: cardiac arrests, code calls, and floor-to-ICU admissions. The modified process evaluation assessed fidelity, reach, and dose delivered as well as staff perceptions.

Results: There was a consistent downward trend in the incidence of cardiac arrests outside the ICUs and in ICU transfers over all 4 years; a Spline regression showed no significant difference. At Memorial, before 1/1/2009, the rate of code calls to the floor was decreasing by 0.0092/1000 patient days for each month until 1/1/2009. After 1/1/2009, the rate of code calls per month increased by 0.0010/1000 patient days. On the University campus, the rate before 1/1/2009 decreased by 0.0012/1000 patient days for each month. After 1/1/2009, the slope was no different from zero, meaning that the rate did not increase or decrease. The process evaluation showed that that the RRS was being used as it was designed, though the nurses were not using the specific triggers as a deciding factor in making the call. Staff satisfaction with the intervention was high.

Key words: rapid response, Spline regression, process evaluation

Purpose

The objective of this study was to evaluate the effectiveness of an RRS in hospitals on the two campuses of the UMass Memorial Medical Center (UMMMC). Additionally, a modified process evaluation explored RRS reach, dose delivered, and fidelity of the implementation to the original design of the RRS. The process evaluation also included an assessment of nursing and other staff perspectives on and attitudes toward the RRS.

Scope

Cardiac arrests that occur outside of the ICU, emergency room (ER), and operating room (OR) are considered unanticipated, meaning that a patient was presumed to have a very low probability of such an event and thus could safely be cared for on a general hospital floor with limited or no cardiac monitoring. Studies have found that approximately 68% of the cardiac arrests may be avoidable. One study determined that 100% of patients with cardiac arrest outside the ICU had not received adequate care in the 24 hours before the arrest, even though there were signs suggesting deterioration in their condition.[1] According to other studies, more than 80%[2,3] of patients experiencing cardiac arrest outside the ICU had observable signs of deterioration before they arrested. Of these patients, depending on the type of antecedent sign, 23%-81% did not receive appropriate care in response to an antecedent sign, in the judgment of the authors.[2] These initial studies suggest that an intervention that identifies these antecedents early and effectively treats the condition(s) underlying the antecedent signs may reduce the rate of cardiac arrests on general hospital floors.

RRSs were developed to intervene when these antecedents are first noticed, before the patient declines more. RRSs typically include an individual or a team of clinicians called to the bedside when a patient's condition meets one or more criteria (trigger) from a pre-determined set of physical signs and symptoms (e.g., abnormally low or abnormally high blood pressure, heart rate, respiratory rate) that commonly mark a clinical decline that may end in cardiac arrest.

Modified Process Evaluation

The modified process evaluation assessed the following domains of the intervention to determine if it was being used as designed: fidelity, the amount that the staff followed protocol; reach, the proportion of the intended patient population that is reached by the RRS; dose delivered, the overall number of interventions by the RRS team; and the perceptions of the hospital staff affected by the RRS with respect to acceptability, satisfaction with the RRS, and barriers to utilization. There have been some studies that have assessed the attitudes and experiences of bedside nurses, who are the most frequent users of an RRS. A study from Australia with a sample size of 73 nurses found that, the more experienced the nurse, the more likely he/she was to use the RRS.[4] In another Australian study, investigators developed a survey and administered it to a sample of 351 nurses.[5] They found that nurses were more likely to call the covering provider before calling the rapid response team (RRT), even though the protocol was to call the RRT first. The authors also found that nurses may be underestimating the significance of the trigger signs and often opt not to call the RRT when trigger signs are present. Investigators in Canada using the same survey (n=275) found similar results.[6]

A study that reported on 50 semi-structured individual interviews of nurses in six California hospitals found that the nurses sometimes used the specified triggers to decide when to activate the RRS, but, for patients who did not meet trigger criteria, they relied on their own clinical knowledge.[7] The authors also found that newer nurses were more likely to consult with a more experienced nurse before calling the RRT, even when this was not part of the protocol. More information regarding how the RRS is being used is needed to better understand RRS outcomes.

Setting

This study was conducted in two hospitals on the main campuses of the UMMMC, located in Worcester, Massachusetts. The hospitals provide care for patients from the city of Worcester and from elsewhere in Worcester County. With more than 700 acute care beds, UMMMC is the largest acute care provider in central Massachusetts. UMMMC hospitals are level-1 tertiary care teaching institutions, with an average admission rate of 3600 patients per month.

Intervention

An RRS was fully implemented in January of 2009 at both UMMMC hospitals following a brief education and pilot period. The RRT consists of the first-call house officer, a Hospital Medicine clinician, a nursing supervisor, and a respiratory therapist. The team can be activated by any clinical staff person when one or more trigger signs are observed (Table 1).

Table 1: UMMMC Rapid Response System Triggers

Heart rate <40
Heart rate >120
Systolic BP <90
Chest pain
Respiratory rate <6
Acute drop in O_2sat to <90%
Significant drop in O_2sat from baseline
FiO_2 >50% or O_2 >6 lpm
Decreased level of consciousness
Agitation, delirium
Possible stroke
Seizure
Marked concern by clinical, staff, patient, or visitor

Clinical staff also has the option to activate the RRT when they are concerned about a patient's condition, even if a specific trigger sign is not observed. The roles and protocols to be followed are described in Table 2.

Table 2: Established Roles and Protocols for Rapid Response Team

Team Member	Role	Protocol
Bedside Nurse	To activate the RRS and to have all necessary patient information ready for team	Use pre-determined criteria to activate team; use SBAR* to communicate with team
Hospital Medicine NP*/PA** or Hospitalist	To offer clinical support; responsible for all documentation associated with RRS	Arrive within 5 minutes of call Complete Rapid Response Record
House Officer	To act as clinical lead	Arrive within 5 minutes of call
Nursing Supervisor	To provide nursing support and resource management	Arrive within 5 minutes of call (nights and weekends only)
Respiratory Therapist	To maintain airway	Arrive within 5 minutes of call

*Nurse Practitioner
**Physician's Assistant

Methods

This was a before/after study design to evaluate the effectiveness of the RRS intervention and a modified process evaluation. The incidence rates of outcomes during the 2 years before the intervention (01/01/2007 to 12/31/2008) and during the 2 years after (1/01/2009 to 12/31/2010) were compared. A pilot RRS model was performed during the last 2 weeks of 2008 on two floors at each hospital. This time period

was included in the before period because of the limited number of floors included in the pilot and RRS calls made. Table 3 shows the outcome measures, definitions, and data sources used in the study.

Table 3: Rapid Response Outcome Definitions and Measures

	RRS Calls	Cardiac Arrests on Hospital Medical and Surgical Floors	Cardiac Arrests Hospital Wide	Cardiac Arrest ICU Only	Code Calls (Floors Only)	Floor to ICU Transfers
Measure description	Rate of Rapid Response calls	Rate of cardiac arrests that occur outside of the ED, OR, ICU or diagnostic areas	Rate of cardiac arrests that occur anywhere in the hospital	Rate of cardiac arrests in the ICU	Rate of code calls received by telecommunications that originate from the floors	Rate of transfers from the floor to the ICU
Operational Definition	A call for the RRT received by telecom-munications	Any cardiac event that required CPR**** or ACLS* was considered as well as all asystole or PEA**	Any cardiac event that required CPR* or ACLS** was considered as well as all asystole or pulseless electrical activity (PEA); includes OR, ED, and ICU	All cardiac arrests that occurred in the ICU requiring CPR or ACLS*, including documented asystole or PEA**	A call for the code team received by telecommunications	Transfers that do not originate from the emergency department or operating room
Denominator	1000 patient days	1000 patient days	1000 patient days	1000 patient days	1000 patient days	1000 patient days
Data collection Method	Rapid Response Event forms and telecom-munication records	Arrests identified by ICD-9 discharge code and verified by medical record review	Arrests identified by ICD-9 discharge code and verified by medical record review	Arrests identified by ICD-9 discharge code and verified by medical record review	Telecommunications records of calls coming from outside of the ICU, ED, and OR	Electronic record

*ACLS: Advanced Cardiac Life Support
**PEA: Pulseless Electric Activity
*** CPR: cardiopulmonary resuscitation

The modified process evaluation evaluated RRS fidelity, reach, dose delivered, and staff perspectives on the RRS.[8] Table 4 shows the domains assessed, the questions addressed by each domain, the targeted populations, and the measures and data sources. To address the staff satisfaction, a survey was distributed to the nursing staff, and a focus group was convened. The information from the survey and focus group were coded to identify themes.

Table 4: Modified Process Evaluation Domains[8]

Domain	Research Question and Related Measures	Target of Evaluation	Measures/Data Source
Fidelity: Nurse and staff performance: Nurse and RRT member performance	Are the RRS protocols being followed? Percent of events for which the RRT arrived in 10 minutes or less Percent of events in which nurses used SBAR	Primary nurse Rapid Response Team	Rapid Response Event Forms
Reach: The proportion of the intended target population that was reached by the Rapid Response Team	What percent of patients who are eligible for an RRS intervention receive one?	Patients	Medical records Meditech Visicu*
Dose delivered: The number of calls that are made to and the response of the Rapid Response System	How many calls were made? RRS interventions	Primary nurses	Rapid Response Event Forms Telecommunications record
Perspective of staff affected	What is the acceptability/satisfaction? What are the barriers to RRS use?	Primary nurses	Focus groups Surveys (individuals)

*Visicu is the electronic records system of the electronic ICU.

Statistical Analysis

There were two study periods for evaluation of cardiac arrests and code calls, 1/01/2007 to 12/31/2008 (before the intervention) and 1/01/2009 to 12/31/2010 (after the intervention). Floor to ICU transfers were evaluated during the 12 months before the intervention and the 24 months after the intervention. The incidence rates of cardiac arrests, unanticipated transfers from the general floor to an ICU, and code calls before and after the intervention were calculated separately. Three statistical tests were used to assess the changes in the rates of the outcomes. Initially, a t test was used to assess change in the mean annual rates. A linear regression was done to evaluate the trend in monthly rates over the entire 4-year study period. Then, a test of significance for the Spline knot at 1/1/2009 was done. If that test was significant, a Spline regression model was used to evaluate differences in the slopes before and after the intervention, using rates of cardiac arrests, code calls, and ICU transfers by month as the dependent variable and study months since 1/01/2007 as the major independent variable. Frequency tables were developed for triggers, bedside interventions, and patient disposition after an RRS intervention.

Results

Rapid Response Calls

There were 683 calls in total, 449 at the University campus and 234 at Memorial, over the 2 years of hospital-wide implementation. The triggers, interventions, and disposition of the patients are detailed in Table 5.

Table 5: Rapid Response Triggers, Interventions, and Disposition

Rapid Response Triggers (some patients had more than 1 trigger)	Memorial (N=97) N (%)	Campus University (N=201) N (%)	Total
Acute drop in O_2sat to <90%	30(31)	82(41)	112
Marked nursing house staff or family	25(26)	63(31)	88
LOC decreased level of consciousness	22(23)	56(28)	78
Heart rate >120	17(18)	32(16)	49
Significant drop in O_2sat from base	12(13)	26(13)	38
Systolic BP <90	12(13)	20(10)	32
Seizure	11(12)	19(9)	30
Heart rate <40	5(6)	13(6)	18
Chest pain	9(10)	13(6)	22
RR rate <6	6(7)	8(4)	14
Agitation/delirium	1(2)	7(3)	8
FiO_2 >50% or O_2 >6 lpm	4(5)	6(3)	10
Trigger unknown	2(3)	4(2)	6
Possible stroke	1(2)	2(1)	3
Urine output low	3(4)	2(1)	5
Interventions*			
Increase oxygen	37(38)	101(50)	138
Order medication	37(38)	82(41)	119
Start oxygen	23(24)	57(28)	80
IV fluid bolus	15(16)	37(18)	52
Nebulizer TX	12(13)	20(10)	32
Tracheal suction	10(11)	12(6)	22
None	4(5)	19(9)	23
Other	26(27)	40(20)	66
Disposition			
Transfer to ICU	42(43)	89 (44)	131
Immediate treatment given trigger/s back to normal	32(33)	59(29)	91
Treatment planned; re-evaluate after treatment	18(19)	54(27)	72
No active treatment given or planned	1(2)	10(5)	11
Change of status to DNR CMO	1(2)	3(1)	4
Other	6(7)	28(14)	34

Frequency distributions of patient characteristics, such as age, gender, etc., were evaluated for differences before and after the intervention. There were no significant differences in patient population for the two time periods (Table 6).

Table 6: Patient Demographics

	Pre-intervention n (%)	Post-interventi n (%)	Pre-intervention n (%)	Post-intervention n (%)
Gender				
Male	12,940 (40)	11,281(39)	18,791 (56)	19,322 (55)
Female	19,770 (60)	17,676 (61)	15,399 (45)	16,135 (45)
Age				
<25	722 (2)	729 (3)	1656 (5)	1608 (5)
25-64	16,347 (50)	15,098 (52)	19,988 (58)	20,181 (57)
65-84	11,637 (36)	9790 (34)	10,071 (29)	10844 (31)
85-94	3635 (11)	3048 (11)	2330 (7)	2619 (7)
95-104	368 (1)	293 (1)	145 (0.4)	207 (1)
105-114	1 (.003)	1 (.003)	0	4 (0.01)
Race				
White	28,41 (86)	25,158 (87)	29,142 (85)	30,618 (86)
Other	1879 (6)	2111 (7)	2616 (8)	2,665 (7.5)
Black	1256 (4)	1278 (4)	1213 (3.5)	1354 (4)
Asian	1,009 (3)	69 (0.2)	537 (1.5)	455 (1.2)
Unknown	110 (0.33)	58 (0.2)	141 (0.4)	202 (0.6)
Refused	61 (0.10)	7 (0.2)	58 (0.1)	69 (0.2)
Native Hawaiian/Pacific Island	33 (0.1)	15 (0.05)	37 (0.1)	11 (0.03)
American Indian/Alaskan Native	14 (0.04)	18 (0.06)	26 (0.07)	18 (0.05)
Hispanic	25 (0.07	0 (0)	31 (0.09)	0
Blank	8 (0.02)	0 (0)	16 (0.04)	0
Total number of patients	32,710	28,959	34,190	35,461
LOS (mean)	3.8	3.8	5	5
LOS total days	122,734	108,464	172,119	179,416

Results for the Spline regression and t test are presented in Table 7. Hospital-wide results include all events occurring on the hospital floors, in the ICUs, and in diagnostic areas; floor-only results include medical/ surgical areas and units but no diagnostic areas.

Table 7: Comparison Before and After Implementation of the RRS t Test, Linear Regression, and Spline Regression Results

UNIVERSITY	Mean rate (n/1000 patient days) Before	Mean rate (n/1000 patient days) After	Difference in mean rates	t test p-value	Linear Regression p-value	Knot significant? (P<0.05)	Spline Regression p-value
Code calls (floors only)	1.47	0.99	0.48	<0.000	<0.000	Yes	<0.000
Cardiac arrest (hospital-wide)	0.957	0.796	0.161	0.071	0.008	No	
Cardiac arrest (floors only)	0.421	0.291	0.13	0.080	0.01	Yes	0.112
Cardiac arrest (ICU only)	2.057	1.972	0.085	0.760	0.20	No	
Floor-to-ICU transfers	14.35	11.40	2.95	<0.000	<0.000	Yes	0.846
MEMORIAL							
Code calls (Floors only)	1.132	1.147	-0.015	0.927	0.951	Yes	0.026
Cardiac arrests (hospital-wide)	0.484	0.278	0.206	0.029	0.002	No	
Cardiac arrests (floors only)	0.231	0.119	0.112	0.07	0.033	No	
Cardiac arrest (ICU only)	1.58	1.13	0.450	0.357	0.233	No	
Floor-to-ICU transfer	16.1	16.3	-0.200	0.822	0.568	No	

There were changes in the code rates at both campuses; at Memorial, in the months before 1/1/2009, the rate of code calls to the floor was decreasing by 0.0092/1000 patient days for each month until 1/1/2009. After 1/1/2009, the rate of code calls per month increased by 0.0010/1000 patient days (Figure 1). On the University campus, the rate before 1/1/2009 decreased by 0.0012/1000 patient days for each month (Figure 2). After 1/1/2009, the change in the rate of code calls was not different from zero, meaning that the slope of least squares regression line was not statistically significant from 0 (Figures 1 and 2).

Figure 1: Code Call Rates at Memorial Campus

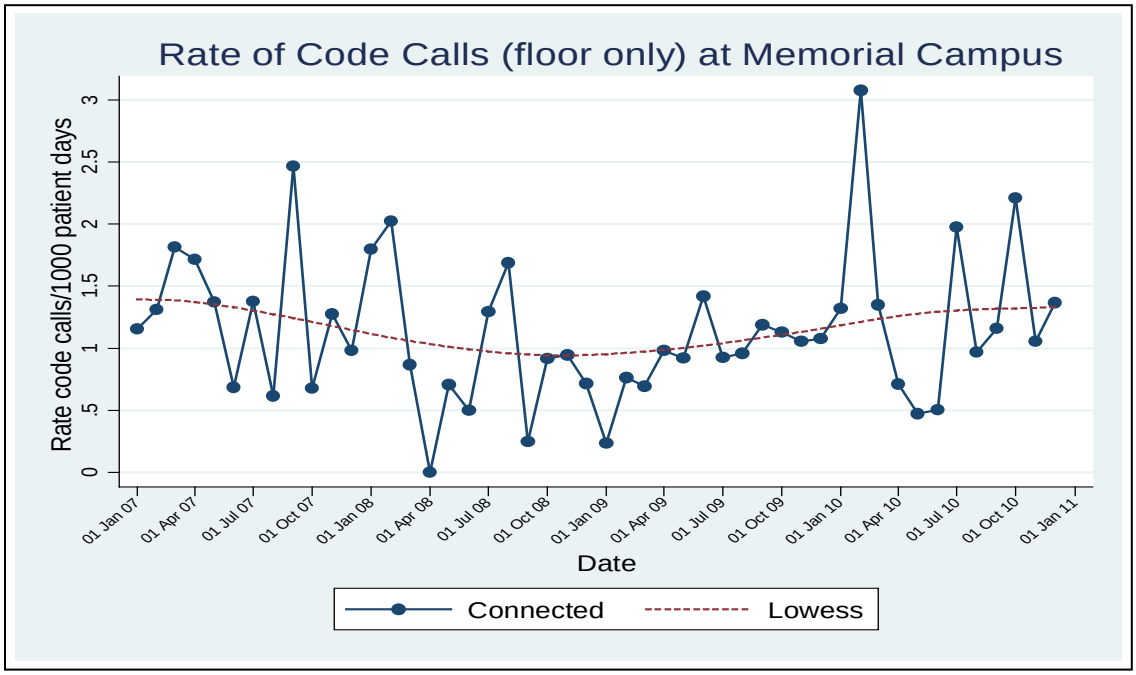
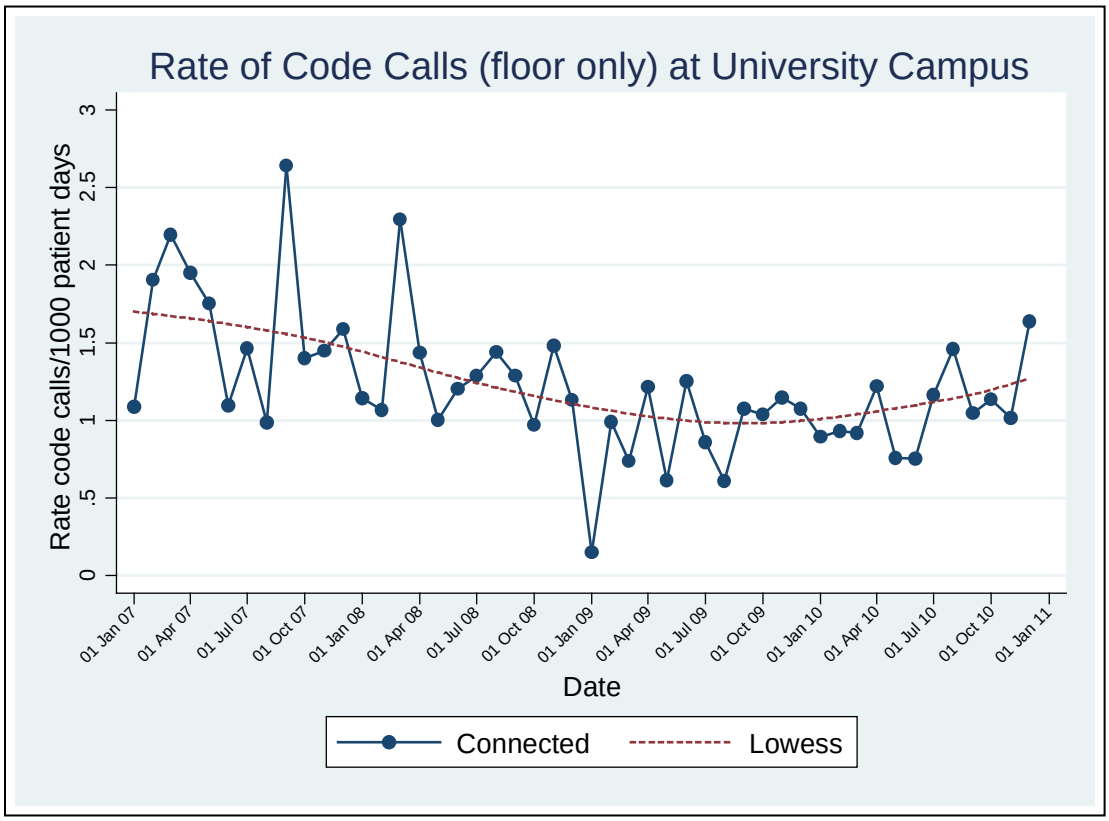


Figure 2: Code Call Rates at University Campus



Cardiac arrests hospital wide on the University campus showed a statistically significant decrease of 0.00027/1000 patient days per month during the entire 4-year study period. However, when comparing the slopes of the before and after periods, there was no significant difference, meaning that the decrease continued at the same rate before and after the intervention. Similarly, on the Memorial campus, there was a statistically significant decrease of 0.0002/1000 patient days per month during the entire 4 years, but there was no difference in slopes when comparing data from before and after the intervention.

Modified Process Evaluation Results

Fidelity

Fidelity of the intervention was primarily evaluated using the Rapid Response Event Records that were used to collect information on the response time of the team, the reporting of the event by the bedside nurse, and the appropriateness of the call. The responding Hospital Medicine clinicians were responsible for filling out the event form. For a total of 683 RRS events, only 338 event records were completed: 202 from University (return rate 45%), 98 from Memorial (return rate 42%), and 38 without information on campus. The forms without campus information could not be used in any analysis that required separation by campus. There were several possible reasons for the low event record completion rate. The forms were available only in hard copy and were not always readily available to the RRT immediately after an event. If an RRS call resulted in no formal intervention, the Hospital Medicine clinician did not see filling out the form as a priority. When the event occurred during a busy day, clinicians may have simply forgotten to complete the event record. There were no substantial differences in the return rate by time, date, or day of the call. During the second year of the intervention, on the University campus, Hospital Medicine physicians took over coverage of the RRS from NPs and PAs during the daytime shifts. This resulted in an even lower overall rate return of the forms, because the physicians as a group consistently had a lower rate of return than the NPs and PAs. Tables 8 and 9 show the response times of the RRS members at the University and Memorial campuses, as estimated by the clinician completing the event record.

Table 8: Response Time (minutes) of the Rapid Response Team (University) Total N=202

Team Member	<=5 n (%)	5-10 n (%)	10-15 n (%)	>15 n (%)	No show n (%)	Not sure n (%)	Missing n (%)
House Officer	122 (60)	23 (11)	3 (2)	6 (3)	7 (3)	4 (2)	37 (18)
Hospital Medicine Clinician	169 (84)	9 (4.5)	1 (.5)	0 (.5)	1 (.5)	0	21 (10)
Respiratory Therapist	147 (73)	9 (4.5)	1 (.5)	1 (.5)	1 (.5)	5 (2)	38 (19)
Bedside Nurse	172 (85)	1 (.5)	0	0	1 (.5)	1 (.5)	27 (13.5)
Nursing Supervisor	101 (50)	12 (6)	3(1.5)	3 (1.5)	12 (6)	10 (5)	61(30)

Table 9: Response Time of the Rapid Response Team (Memorial)

Team Member	<=5 n (%)	5-10 n (%)	10-15 n (%)	>15 n (%)	No show n (%)	Not sure n (%)	Missing n (%)
House Officer	55 (56)	6 (6)	3 (3)	2 (2)	3 (3)	0	29 (30)
Hospital Medicine Clinician	74 (76)	9 (10)	0	0	0	0	15 (15)
Respiratory Therapist	77 (79)	3 (3)	0	0	1 (1)	0	17 (18)
Bedside Nurse	79 (81)	0	0	0	0	1 (1)	18 (18)
Nursing Supervisor	58 (59)	5 (5)	1 (1)	1 (1)	0	4 (4)	29 (30)

Table 10: Nurses' Use of SBAR (Situation, Background, Assessment, Recommendation) (Rated by responding RRT using a three-part scale of completeness)

	University N=202				Memorial N=98			
SBAR Item	Incomplete	Somewhat complete	Complete	Missing	Incomplete	Somewhat complete	Complete	Missing
Situation	17	68	101	16	3	38	41	16
Background	21	77	77	27	5	36	39	18
Assessment	14	62	101	25	7	32	40	19
Recommendation	63	0	119	25	60	0	22	16

The beside nurses' protocol included providing information to the other team members using the SBAR format. The responding Hospital Medicine clinician rated the bedside nurses on how well they used SBAR to

provide clinical information. The results are shown in Table 10. All responders were asked via the event record to comment on whether the call to the RRT was appropriate or if another type of intervention would have been more appropriate (Table 11). The most concerning of these responses are the cases when the team felt that a code call would have been most appropriate for the patient. The education of nurses stressed that a life-threatening condition should lead to a code call and that, if there was any doubt, the code team should be called.

Table 11: Appropriateness of Rapid Response Calls

	University (%)	Memorial (%)	Total (%)
Rapid response call was appropriate for this patient	141(70)	61 (62)	202 (67)
More appropriate response (for cases when RRT call was not appropriate)			
Code call	15 (7)	6 (6)	21 (7)
Routine page to LIP	22 (11)	7 (7)	29 (9)
Routine page to respiratory Therapy	1 (.5)	1(1)	2 (.7)
Could have been handled by nursing alone	1(.5)	0 (0)	1 (.33)
Missing	22 (11)	23 (23)	45 (15)
Total	202 (100)	98 (100)	300 (100)

Reach

Evaluating reach proved a difficult task, given the limitations of available data. There was only a small percentage of code calls that had a corresponding RRS call on both campuses. After the intervention, there were 129 cardiac arrests on the floor at University, and there were 29 arrests on the floor at Memorial.

Of the arrests after the intervention, only three were associated with a RRS call within 24 hours before the arrest. All of these were at the University campus. Without a paper chart review, it was not possible to determine if any antecedents were present 24 hours before the arrest. Code calls at UMMMC are not recorded with patient identifiers, so, when a code sheet is not filled out (which happens when the call does not require use of medications and supplies in a code cart), it is impossible to determine what the other code calls were for. Both before and after the intervention, less than 50% of all code calls had corresponding codes sheets.

Dose Delivered

There were 683 rapid response calls: 449 at the University campus, and 234 at Memorial. The University campus averaged 18 calls per month, with a range from nine to 32 and an average rate of 2.8 calls per 1000 patient days. The Memorial campus averaged 10 calls per month, with a range from two to 21 and an average rate of 2.3 calls per 1000 patient days. There was no statistically significant increase or decrease over the 24-month study period.

Staff Perspective

A focus group of seven medical/surgical bedside nurses resulted in responses to five different areas; these responses were coded for themes and are described in Table 12. According to the nurses involved in the focus group, the RRS has improved the method of getting the House Officer to focus on their patients, but they generally did not use the designated triggers as part of their decision to activate the RRS. Each of 10 nursing managers was given 20 surveys, and 27 surveys overall were returned. Of those who responded, the majority felt that the RRT prevents cardiac arrests and transfers to the ICU as well as helps manage sicker patients outside of the ICU. Most nurses reported calling for the RRT when their patients were sick and they could not reach a covering physician, though they also reported, in most cases, trying to contact a physician first. Overall, there was no concern reported about being criticized for calling the RRT or about overusing the intervention.

The Hospital Medicine clinicians' comments from the event records were reviewed and grouped into common themes. The most notable comments were about RRS calls perceived by the clinician as unnecessary, including one call on a patient with do not resuscitate (DNR) and do not intubate (DNI) orders, and about the psychiatry floor, which was inadequately equipped to support the needs of the RRT.

Table 12: Focus Group Themes

When the Bedside Nurse Decided to Call

- When things were going badly but it was not a code
- When the covering physician was not responding
- When there seemed like there were no other options
- When there was uncertainty about a situation

Usage of the Trigger Criteria

- Do not refer to the list often
- Didn't know there were trigger criteria
- Rely on a "gut" feeling
- Some of the trigger criteria are normal for surgical and other patients

Reasons that the Bedside Nurses Waited to Call or Did Not Call at All

- Called the resident first and finally insisted that they deal with it or an RR would be called
- Borderline cases waited to see if they would turn with standard interventions
- Newer nurses tend to ask the more experienced nurses before calling themselves

Concerns from the Bedside Nurses

- When first implemented, there was a slow response time
- The House Officer is not always an effective part of the team
- Sometimes, the covering physician is not happy that the RR was called, even if they were not responding to the bedside nurse's concerns

Benefits of the Rapid Response Team

- Covering MD is quicker to respond if they know an RR has been called
- The RR is a fallback or safety net when the bedside nurse is out of options
- The RR is able to facilitate faster ICU transfers
- Provides someone to call when the covering physician is unavailable or it is unclear who is covering the patient
- Provides clinical support to a new intern
- Very good interactions with the responding Hospital Medicine clinicians
- It has made the bedside nurse's job easier
- Probably prevented codes and saved lives
- RRT will show up when called
- Newer nurses are being taught by the responding team
- Other nurses will take over the patients of a nurse who has called for an RR

Discussion

This study identified minimal but statistically significant differences in outcomes during the periods before and after the RRS intervention. The most notable differences were in the code calls on the University and Memorial campuses. On the University campus, there was a statistically significant decrease in the mean rate of code calls between the before and after periods. However, the Spline regression showed that the slope after the intervention did not differ significantly from 0. This could mean that there was a decrease in code calls during the time period before and that the intervention stopped the decline. A more logical explanation is that around 1 call per 1000 patient days is the lowest that could be expected for the rate of code calls on the floor. Having the RRS in place may have helped to stabilize the rate of code calls at this low level.

On the Memorial campus, there was a slight increase in code calls over the 4 years and an upward trend during the after period. The RRS did not seem to impact the rate of code calls on the Memorial campus. On the University campus, there was a decrease in code calls before the intervention and a leveling off after the intervention. If the maintenance of a low level of code calls on the University campus is related to the RRS implementation, then this finding is likely due to a shift of calls to the RRS that in the past would have gone to the code team even when they were not life-threatening events.

There was no statistically significant change in the rate of cardiac arrests between the before and after periods that could be attributed to the intervention; however, there was a significant decline that began before the intervention and continued throughout the study period. Preventing cardiac arrests hospital wide is an ongoing improvement process for most hospitals. The RRS may or may not have contributed to observed decline. It is possible that, if the RRS were activated more frequently or if the after period was longer than 2 years, an effect of the intervention might be identified. The findings on cardiac arrests on the medical/surgical floors were similar to those hospital wide. Cardiac arrests declined over the entire 4 years without a significant difference in rate of decline after the intervention.

The implementation of an RRS not only is a change in protocols and procedures but also is a cultural change. Currently, based on the reason for calls and the descriptions of the patients given on the event record,

the calls are coming in for patients who are well into a clinical decline. The nurses are likely not using the trigger criteria explicitly when deciding to activate the RRS. With more education of nurses and perhaps more effective specification and use of trigger criteria, it may be possible to get staff to activate the RRS earlier in patients' clinical decline. This could impact the rate of cardiac arrests on the floors. Additionally, though not part of this study, patients and visitors are now able to directly activate the RRS. Further evaluation would be necessary to determine if encouraging patients and families to call the RRT will change the number of calls, the patient conditions leading to calls, and the impact these calls have on preventing cardiac arrests on the floors.

There was not a statistically significant change in the rate of cardiac arrests in the ICU. The RRS would not necessarily be expected to reduce this rate unless early intervention before patients are transferred to the ICU reduces the risk of these ICU patients experiencing cardiac arrest. If the RRS was just shifting the occurrence of some cardiac arrests from the floor to the ICU, the ICU arrest rate would actually increase. The majority of patients with a RRS call were transferred to the ICU; it is not clear from the data if some of these transfers could have been prevented with an earlier RRS activation. Another evaluation of floor-to-ICU transfers could identify if patients being transferred earlier in the disease process might contribute to a shorter length of stay and reduced mortality rates.

Rates of floor-to-ICU transfers on the University campus declined over the entire study period (3 years), but there was no statistically significant difference between the rate of decline before versus after the intervention. On the Memorial campus, there was no decline in ICU transfers at all during the study period. A reduction in floor-to-ICU transfers would not necessarily be expected with an effective RRS, but ICU transfers should occur earlier in the course of patients' clinical decline. We were not able to determine the timing of ICU transfers during the process of clinical decline.

Some studies suggest that July may be a dangerous month to be a patient in a teaching hospital, because this is the month when less-experienced house staff become responsible for patient care. Because the RRS at UMMMC includes a hospital-based clinician and because house staff are able to activate the system, they and the RRS essentially serve as a bridge during this time period. Future studies should examine the effect of the RRS during multiple years, which could identify reduced mortality and/or morbidity related just

to its utilization by inexperienced house staff during multiple Julys. Additionally, the RRS serves as another method to provide teachable moments to the new house staff.

There are only a small number of published process evaluations performed to determine if an RRS is working as designed. It is difficult to evaluate the process of implementation and usage of an RRS and how it affects the outcomes. At UMMMC, the RRS was most often used as it was designed, to be activated when a nurse or other staff member noted significant signs of clinical decline in a patient. There were some cases, however, in which the nurses used the RRS as a negotiating tool, telling House Officers that if they did not come to the bedside right away, they would call the RRS. This is one way that the availability of the RRS alone may change the way care comes to the bedside apart from formal RRS activation. It also appears that bedside nurses view the RRTs as a readily accessible educational resource. They are able to ask questions and get information that makes them more confident in their care of patients. Although the RRS was not explicitly designed to make House Officers more responsive to nurses' calls and to serve as an educational resource for nurses, documenting the existence and use of these RRS features provides insight into ways the RRS can, over time, change the interaction among staff and the hospital culture for the better. This modified process evaluation showed that there are components in each area (fidelity, reach, dose, and staff perspectives) that could have contributed to the outcomes of the study both positively and negatively. However, more importantly, it shows that this intervention has been well received by the staff, especially the bedside nurses, and has the possibility of increased usage over time, which may show better clinical outcomes as well.

Study Limitations

There were several limitations to this study. The most prominent was the difficulty in obtaining the required data over a period of several years. The methods and quality of documentation of RRS events changed during the study period with implementation of a new billing and medical record software as well as multiple staff changes. The verification of cardiac arrests required cross-referencing of ICD-9 discharge codes with electronic progress notes to determine the actual occurrence of an arrest and the location and outcome of the arrest. The clinician documentation for an arrest, ICU transfer, and activation of the RRS was limited and

incomplete in terms of the detail of the cardiac events, the clinician's thoughts about the patient condition, and the treatment plan, thereby limiting the amount of data available for analysis.

Though not as strong a study design as a randomized controlled trial, before-and-after, single-site studies are the most feasible and acceptable alternative for evaluating the effectiveness of a RRS intervention. There were no other known interventions that could have impacted the changes we identified from the before versus after period, but not all interventions or initiatives were known to the investigators. Changes in any one of these factors from the pre- to post-intervention period could have an independent effect on the outcomes being measured in an RRS study.

Conclusion

Similar to the results of other studies in the literature, the results of this study were inconclusive in terms of outcome related to the RRS implementation. This serves as additional evidence that the methods and outcomes used to study RRS may not be the most effective. This study attempted to establish standard definitions and measures in the evaluation of the RRS. This was not always possible, given that much of the needed data were not available. Additional research should explore not only better methods for studying RRSs but also better overall methods for evaluating hospital-based quality improvement interventions.

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