Impact of an Intensivist-Led Multidisciplinary Extended Rapid Response Team on Hospital-Wide Cardiopulmonary Arrests and Mortality*

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Objective: The effectiveness of rapid response teams remains controversial. However, many studied rapid response teams were not intensivist-led, had limited involvement beyond the initial activations, and did not provide post-ICU follow-up. The objective of this study was to examine the impact of implementing an intensivist-led multidisciplinary extended rapid response team on hospital-wide cardiopulmonary arrests and mortality.

Design: This was a pre-post rapid response team implementation study.

Setting: Tertiary care academic center in Saudi Arabia.

Patients: A total of 98,391 patients in the 2-yr pre-rapid response team and 157,804 patients in the 3-yr post-rapid response team implementation were evaluated.

Intervention: The rapid response team was activated by any health care provider based on pre-defined criteria and a four-member intensivist-led multidisciplinary rapid response team responded to provide the necessary management and disposition. The rapid response team function was extended to provide follow-up until clinical stabilization. In addition, the rapid response team provided a mandatory post-ICU follow-up for a minimum of 48 hrs.

Measurements and Main Results: The primary outcomes were cardiopulmonary arrests and mortality. After rapid response team implementation, non-ICU cardiopulmonary arrests decreased from 1.4 to 0.9 per 1,000 hospital admissions (relative risk, 0.68; 95% confidence interval, 0.53–0.86; $p = 0.001$) and total hospital mortality decreased from 22.5 to 20.2 per 1,000 hospital admissions (relative risk, 0.90; 95% confidence interval, 0.85–0.95; $p < 0.0001$). For patients who required admission to the ICU, there was a significant reduction in the Acute Physiology and Chronic Health Evaluation II scores after rapid response team implementation from 29.3 ± 9.3 to 26.9 ± 8.5 ($p < 0.0001$), with reduction in hospital mortality from 57.4% to 48.7% (relative risk, 0.85; 95% confidence interval, 0.78–0.92; $p < 0.0001$). Do-not-resuscitate orders for ward referrals increased from 0.7 to 1.7 per 1,000 hospital admissions (relative risk, 2.58; 95% confidence interval, 1.95–3.42; $p < 0.0001$) and decreased for patients admitted to ICU from the wards from 30.5% to 26.1% (relative risk, 0.86; 95% confidence interval, 0.74–0.99; $p = 0.03$). Additionally, ICU readmission rate decreased from 18.6 to 14.3 per 100 ICU alive discharges (relative risk, 0.77; 95% confidence interval, 0.66–0.89; $p < 0.0001$) and post-ICU hospital mortality from 18.2% to 14.8% (relative risk, 0.85; 95% confidence interval, 0.72–0.99; $p = 0.04$).

Conclusion: The implementation of rapid response team was effective in reducing cardiopulmonary arrests and total hospital mortality for ward patients, improving the outcomes of patients who needed ICU admission and reduced readmissions and mortality of patients who were discharged from the ICU. (*Crit Care Med* 2013; 41:506–517)

Key Words: health service administration; hospital mortality; ICU; patient safety; quality improvement; rapid response team

***See also p. 679.**

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In its 1999 report, "To Err Is Human (1)," the Institute of Medicine (IOM) estimated that 48,000 to 98,000 hospitalized patients died annually in the United States as a result of medical errors, including preventable cardiopulmonary arrests. In 2004, the Institute for Healthcare Improvement (IHI) launched its 100,000 Lives Campaign, which recommended the implementation of rapid response teams (RRTs). These teams were proposed to facilitate early detection and treatment of acute clinical deterioration in hospitalized patients with the premise that such intervention would lead to reduction in cardiopulmonary arrests and preventable inpatient deaths (2). As a result, many hospitals worldwide have implemented RRTs supported by several studies demonstrating effectiveness of this intervention (3–6). However, considerable controversy arose after increasing evidence showing no impact of RRT on the rate of hospital-wide cardiopulmonary arrests (7–9) and therefore, doubting the basic concept of RRT. Other studies showed reduction in cardiopulmonary arrest but no change in hospital mortality, which was considered the most meaningful outcome (10, 11). As a result, it has been suggested that there is no robust evidence to support RRT effectiveness (10, 11). However, it is important to note that the studied RRTs varied in staffing models, often were not intensivist-led, had limited involvement beyond the initial activations, and did not provide post-ICU follow-up.

Therefore, it remains unclear what is the impact on patient outcomes, in particular mortality, of implementing an intensivist-led multidisciplinary extended RRT, in which the team does not only respond to RRT activations but also provide follow-up until clinical stabilization and provide routine post-ICU follow-up for patients who were discharged from the ICU; and hence, our study.

METHODS

Setting

The study was conducted in a 900-bed tertiary care academic hospital accredited by the Joint Commission International. The hospital provides general and tertiary clinical services. During the study periods, hospital wards had a nurse/patient ratio of 1:4 with vital signs routinely checked every 4 hrs. Primary medical teams evaluated patients during daytime; and in-house on-call resident physicians provided care as needed during afterhours. The hospital does not mandate advance directives, and do-not-resuscitate (DNR) options are not routinely discussed with the patient or family at admission. The 21-bed medical-surgical ICU admits approximately 1,000 patients yearly and is managed as a closed unit by board-certified critical care physicians on a 24-hr/7-day in-house basis as described elsewhere (12).

Study Design

This was a pre-post RRT implementation study. The 2-yr pre-RRT period (January 2006 to November 2007) was compared to the 3-yr post-RRT period (December 2007 to December 2010). During the study period, there was no change in the hospital admission criteria, nursing or medical care plans nor had major change in the staffing structure. Approval was obtained from the Institutional Review Board of the hospital.

Pre-RRT Period

In the pre-RRT period, the response to unstable patients in hospital wards followed a traditional hierarchy starting from the bedside nurse escalating in a stepwise approach to the "first-on-call" physician, the senior resident, and then the attending physician with several cycles of evaluation and management. The ICU team involvement was typically sought later and followed a similar hierarchy.

Implementation of RRT

The RRT intervention was implemented as a plan-do-study-act project with the aim of reducing unanticipated non-ICU cardiopulmonary arrests. Preparation for RRT implementation started in February 2007. At that time, the institutional leadership supported the project as an urgent patient safety initiative. A committee planned the RRT implementation and conducted extensive evidence-based review to identify the most appropriate structure and activation criteria. In addition, the team developed data collection forms, RRT database, training tools, posters, and governing policy and procedure. Seminars and simulation-based training courses were provided to hospital staff to introduce the RRT and to facilitate their "buy-in." As a result, the RRT was structured as a system of four components (13) to cover all adult medical, surgical, obstetric, and gynecologic wards but not the cardiac wards that were located in a different building. In addition, the RRT covered in-patients who deteriorated while they were outside their wards such as in the radiology, endoscopy, or hemodialysis unit. The *afferent component* included the process for event detection and response triggering. The RRT would be activated by any health care provider via an overhead call and a numerical paging message. The physiologic-based RRT triggers included a) respiratory criteria (threatened airway, respiratory rate ≤ 8 or ≥ 30 breaths/min, oxygen saturation ≤ 90% on an F_{IO_2} ≥ 50% or ≥ 6 L/min), b) cardiovascular criteria (systolic blood pressure ≤ 90 or ≥ 200 mm Hg, heart rate ≤ 40 or ≥ 130 beats/min), c) renal criteria (urine output ≤ 100 mL over 4 hrs for patients with indwelling urinary catheter), d) neurologic criteria (decreased level of consciousness by ≥ 2 points on Glasgow Come Scale [GCS] or repeated seizures), or e) any serious concern about the patient's clinical condition. The *efferent (crisis response) component* was led by a board-certified intensivist and consisted of an ICU fellow or registrar, a critical care nurse, and a respiratory therapist. The activation also involved the bedside nurse, the ward charge nurse, the ward respiratory therapist, and the ward physician. The team had to respond within a maximum of 15 mins of activation as per policy. Upon RRT arrival, the ward staff had to communicate with the team and document the context of activation using Situation-Background-Assessment-Recommendation format. The RRT would then evaluate and provide emergency management to the patient on the ward, arrange for transfer to the

TABLE 1. Description of New Rapid Response Team Activations and Follow-Ups

RRT activations from different hospital wards ($n = 2879$)	
Staff activating RRT, *n* (%)	
Nurse	1779 (61.8)
Physician	1100 (38.2)
Activation triggers, *n* (%)	
Cardiovascular	1508 (52.4)
Respiratory	1365 (47.4)
Neurologic	746 (25.9)
Serious concern	665 (23.1)
Renal	138 (4.8)
Response time (min), median (Q1–Q3)	5 (4–5)
RRT interventions for new activations	
Pharmocologic interventions, *n* (%)	
Intravenous crystalloid bolus	1379 (47.7)
Diuretics	373 (13.0)
Bronchodilators	326 (11.3)
Intravenous human albumin bolus	316 (11.0)
Intravenous antimicrobial therapy	250 (8.6)
Steroids	192 (6.7)
Sedatives	188 (6.5)
Vasoactive infusions	146 (5.1)
Antiarrhythmic agents	137 (4.8)
Electrolyte replacement	129 (4.5)
Antihypertensive agents	118 (4.1)
Nonpharmacologic interventions, *n* (%)	
Respiratory management	
Oxygen supplement	1876 (65.2)
Suctioning	402 (14.0)
Noninvasive ventilation	233 (8.1)
Intubation	117 (4.1)
Monitoring	
Pulse oximetry	2763 (96.0)
Noninvasive blood pressure measurement	2746 (95.4)
12-lead electrocardiogram	1540 (53.5)
Continuous cardiac monitoring	1144 (39.7)
Vascular access	
Peripheral line	771 (26.8)
Central venous catheter	163 (5.7)
Consultations of other services	414 (14.4)
Transfusion of blood products	179 (6.2)
Increased nursing acuity	106 (3.7)
Diagnostics tests	
Chest x-ray	1678 (58.3)
Laboratory tests	880 (30.6)
Computed tomography scan of head/chest/abdomen	289 (10.0)
Other radiologic investigation	80 (2.8)
Follow-up of RRT activations, median (Q1–Q3)	
Number of visits per patient	3 (1–6)
Duration of follow-ups, d	1 (1–2)
Disposition of RRT activations, *n* (%)	
Patients stayed on the ward	1710 (59.4)
Patients admitted to the ICU	1158 (40.2)
Patients admitted to another critical care area	11 (0.4)
Post-ICU discharge follow-ups, median (Q1–Q3) ($n = 2523$)	
Visits per patient	4 (2–6)
Duration of follow-ups, d	2 (2–3)

RRT = rapid response team.

ICU if needed, and initiate discussion of DNR status if appropriate. For patients who were managed on the wards, the team provided follow-up until stabilization. The RRT also provided a mandatory follow-up of a minimum of 48 hrs for all patients discharged from the ICU. The *quality improvement component* involved the development of a database to monitor RRT activations and their outcomes. The *administrative component* consisting of the RRT committee oversaw the function of the intervention and reported to hospital administration. In the 3-month period before RRT implementation, the RRT committee selected certain ICU registrars, senior ICU nurses, and respiratory therapists to be RRT members. They received a 2-day structured simulation-based course on RRT with focus on improving communication skills, crisis management, and teamwork. Four weeks before RRT implementation, a start-up hospital-wide campaign was conducted to educate medical and nursing ward staff on trigger criteria, team roles, and responsibilities. The campaign included the distribution of posters, pamphlets, and handouts. In addition, didactic presentations were repeatedly provided to ward nurses and physicians during their handover sessions and departmental meetings with the aim of reaching as many staff as possible. The RRT was officially launched on November 23, 2007, with an inauguration ceremony attended by the institutional leadership and hospital staff from various departments. In the following 3 yr, multiple

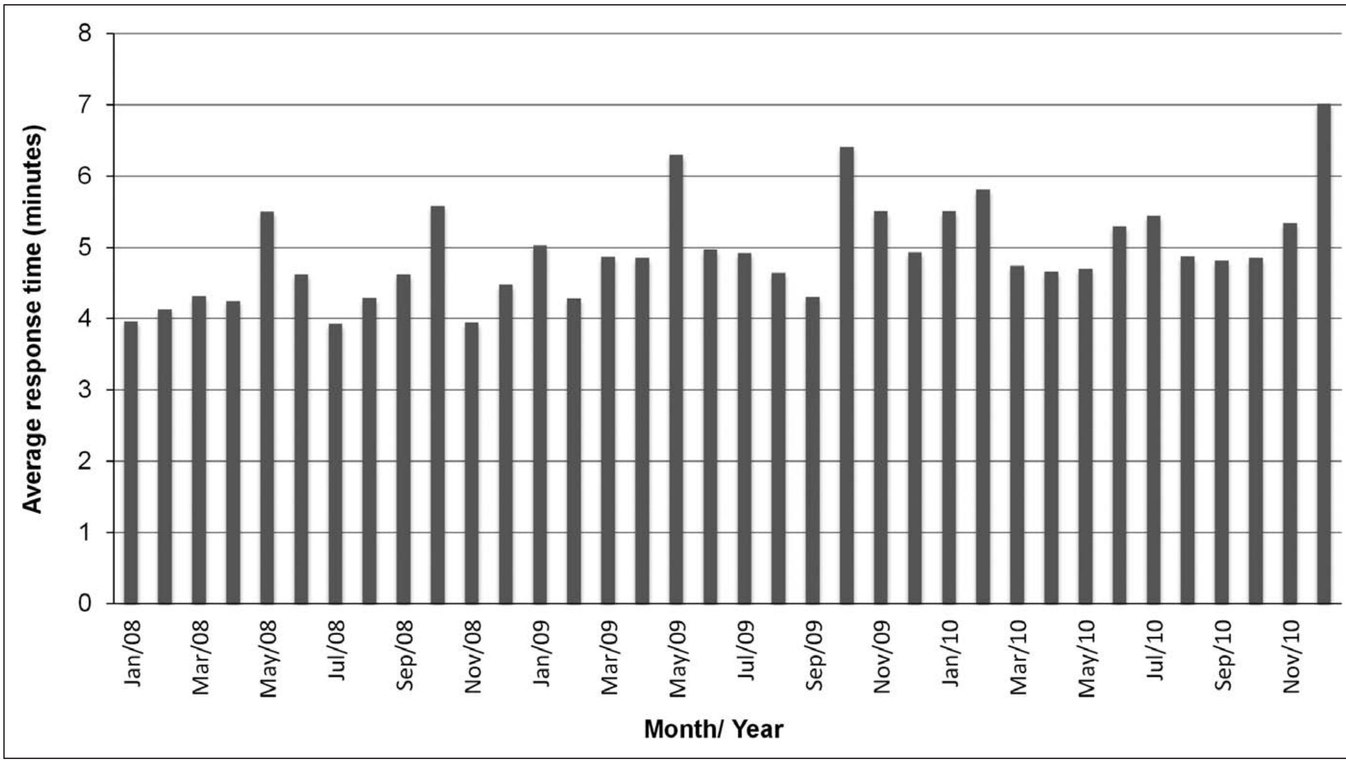

Figure 1. Rapid response team response time in minutes.

interventions were undertaken to facilitate culture change and maintain hospital-wide acceptance. The RRT committee met regularly to oversee the performance and to provide feedback to different wards and services especially if there was an increase in cardiac arrests or reports of delays of RRT activation. RRT awareness days were conducted every 6 to 12 months, during which hospital-wide posters on RRT activation were placed and the hospital staff were invited to attend a 2-day symposium in which the RRT team presented their achievements and challenges and obtained feedback and suggestions for improvement from attendees. Simulation-based courses were provided to nurses and physicians every 6 to 12 months. In addition, a specific session about RRT was added to the new employee orientation program for both physicians and nurses. The cardiopulmonary arrest team, led by an emergency care attending, remained functional and separate from RRT.

Data Collection and Outcome Measures

Data were obtained from the hospital information system, records of the cardiopulmonary resuscitation committee, and from the prospectively collected ICU and RRT databases. RRT response time was defined as the time from RRT activation to the arrival at the bedside in minutes. To examine the effect of RRT on the care of ward patients, we compared the pre- and post-RRT rates (per 1,000 hospital admissions) of referrals to ICU service from the wards, non-ICU cardiopulmonary arrests, initiation of DNR status, transfers to ICU from the ward including transfers to ICU following cardiopulmonary arrests, ward mortality (divided into anticipated ward mortality for DNR patients and unanticipated ward mortality for full-code patients), and total hospital mortality (calculated as the sum of ward and ICU mortality). To examine the effects of RRT on the patient mix and outcomes of ICU patients admitted from the wards, we compared the pre- and post-RRT periods for the admission characteristics including demographics, Acute Physiology and Chronic Health Evaluation (APACHE) II score (14), main reason for ICU admission, the presence of severe chronic illness as defined by APACHE II, predicted mortality by Mortality Probability Models (MPMs) II_0 (15) and APACHE II, the presence of indicators of organ failures in the first hour of admission as defined by MPM II_0 system; including coma (GCS < 6), severe tachycardia (> 150/min), hypotension (systolic blood pressure < 90 mm Hg), acute kidney injury (creatinine > 176.8 µmol/L), and the need for mechanical ventilation. We also compared the two periods for the number of patients who had DNR orders after ICU admission and the number of patients who had cardiopulmonary arrest in the ICU, the need for tracheostomy, mechanical ventilation duration, ICU and hospital length of stay (LOS), and ICU and hospital mortality. Because the intervention included mandatory post-ICU follow-up, we compared the two periods for the ICU readmission rates and post-ICU mortality, and LOS.

Statistical Analysis

All statistical analyses were performed using SAS software (version 9.1; SAS Institute, Cary, NC). Continuous variables were presented as medians and quartiles 1 and 3 (Q1–Q3) or means and SD as appropriate, and categorical variables as absolute and relative frequencies (%). Student *t* test and chi-square test were used to compare differences between the groups. Relative risk (RR) and 95% confidence inter-

TABLE 2. Outcomes of Ward Patients in the Pre- and Post-Rapid Response Team Implementation

	Pre-RRT	Post-RRT	*p*
Hospital admissions			
Number	98,391	157,804	
Referrals to ICU			
Number	1,497	2,879	
Rate per 1,000 admissions	15.2	18.2	< 0.0001
Relative risk (95% CI)	1.20 (1.13–1.28)		
Non-ICU cardiopulmonary arrests			
Number	133	144	
Rate per 1,000 admissions	1.4	0.9	0.001
Relative risk (95% CI)	0.68 (0.53–0.86)		
Patients in whom ICU/RRT team initiated do-not-resuscitate order			
Number	65	269	
Rate per 1,000 admissions	0.7	1.7	< 0.0001
Relative risk (95% CI)	2.58 (1.95–3.42)		
Patients transferred to ICU			
Number	856	1158	
Rate per 1,000 admissions	8.7	7.3	< 0.0001
Relative risk (95% CI)	0.84 (0.77–0.92)		
Patients transferred to ICU post cardiopulmonary arrest			
Number	99	108	
Rate per 1,000 admissions	1.0	0.7	0.0005
Relative risk (95% CI)	0.68 (0.51–0.90)		
Ward mortality			
Number	1,912	2,829	
Rate per 1,000 admissions	19.4	17.9	0.006
Relative risk (95% CI)	0.92 (0.87–0.98)		
Anticipated ward mortality			
Number	1878	2793	
Rate per 1,000 admissions	19.1	17.7	0.01
Relative risk (95% CI)	0.93 (0.88–0.98)		
Unanticipated ward mortality			
Number	34	36	
Rate per 1,000 admissions	0.3	0.2	0.08
Relative risk (95% CI)	0.66 (0.40–1.08)		
Total hospital mortality			
Number	2,214	3,191	
Rate per 1,000 admissions	22.5	20.2	< 0.0001
Relative risk (95% CI)	0.90 (0.85–0.95)		

RRT = rapid response team; CI = confidence interval.

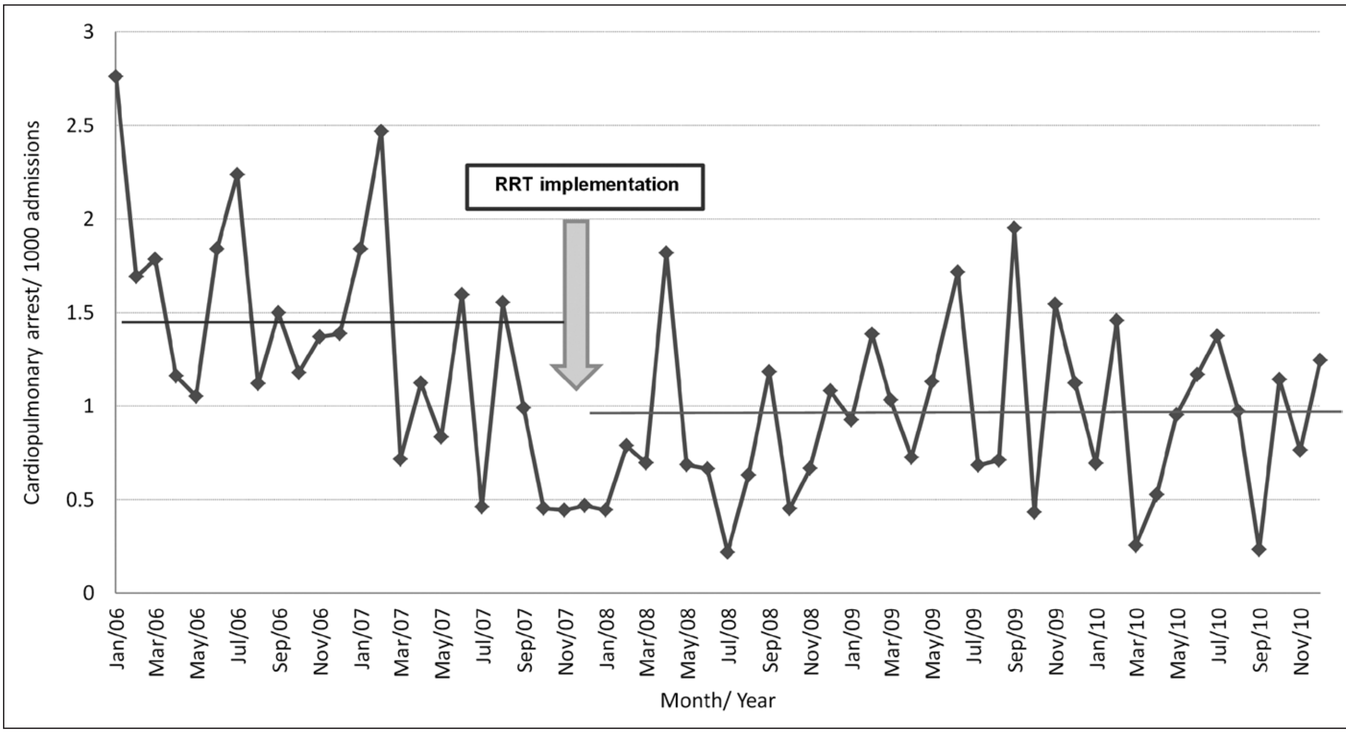

Figure 2. Run chart of non-ICU cardiopulmonary arrests pre- and post-rapid response team (RRT) implementation.

vals (CIs) were reported for categorical outcomes. Standardized mortality ratios (SMRs) for APACHE II and MPM II_0 were calculated by dividing the actual by predicted hospital mortality with corresponding 95% CIs (16). We carried out stratified analyses for hospital mortality of patients admitted to ICU in the pre- and post-RRT periods by admitting service (medicine, surgery, obstetrics, and orthopedics). To examine whether there was any difference in hospital population patient mix between the two periods, we compared APACHE II scores and hospital mortality for non-RRT admissions to ICU from the operating room and emergency department. The p value ≤ 0.05 was considered to be statistically significant.

RESULTS

There were 98,391 and 157,804 hospital admissions in the 2-yr pre-RRT and 3-yr post-RRT implementation, respectively. After RRT implementation, there were 2,879 RRT activations reflecting an increase in referrals to ICU service from 15.2 to 18.2 per 1,000 hospital admissions (RR 1.20; 95% CI 1.13–1.28; $p < 0.0001$).

RRT Activations, Interventions, and Follow-Ups

As shown in **Table 1**, ward nurses activated RRT more often than physicians (1,779 activations [61.8%] vs. 1,100 activations [38.2%]), with cardiovascular and respiratory abnormalities being the most common triggers. Serious concern about a patient condition by the ward staff was the trigger for 665 (23.1%) activations. The median RRT response time was 5 mins (Q1–Q3: 4–5) (Table 1 and **Fig. 1**). The RRT provided a variety of diagnostic and therapeutic interventions (Table 1). Most patients cared for by RRT remained in the wards (59.4%); the rest required admission to critical care units. The RRT provided a median of three visits per activation (Q1–Q3: 1–6) for a median of 1 day (Q1–Q3: 1–2). In addition, RRT provided follow-up to 2,523 patients after discharge from the ICU for a median of four visits per patient (Q1–Q3: 2–6) over 2 days (Q1–Q3: 2–3).

RRT Impact on the Outcomes of Patients on Hospital Wards

Non-ICU cardiopulmonary arrests decreased from 1.4 to 0.9 per 1,000 hospital admissions (RR 0.68; 95% CI 0.53–0.86; p = 0.001) (**Table 2** and **Fig. 2**) and transfers to ICU after cardiopulmonary arrests decreased from 1.0 to 0.7 per 1,000 hospital admissions (RR 0.68; 95% CI 0.51–0.90; $p = 0.0005$). The ward mortality decreased from 19.4 to 17.9 per 1,000 hospital admissions (RR 0.92; 95% CI 0.87–0.98; $p = 0.006$); the reduction was observed in both anticipated and unanticipated ward mortality. Total hospital mortality decreased from 22.5 to 20.2 per 1,000 hospital admissions (RR 0.90; 95% CI 0.85–0.95; $p < 0.0001$). Transfers to the ICU decreased from 8.7 to 7.3 per 1,000 hospital admissions (RR 0.84; 95% CI 0.77–0.92; $p < 0.0001$).

RRT Impact on the Outcomes of Patients Admitted to ICU from Hospital Wards

After RRT implementation, the number of patients admitted to the ICU from the wards decreased as mentioned earlier. In addition, there were several changes to the characteristics and outcomes of these admissions (**Table 3**). The severity of illness for admitted patients decreased after RRT implementation as reflected by reduction in APACHE II scores and by reduction in the presence of organ failure indicators on admission, including coma, severe tachycardia, hypotension, and requirement of

TABLE 3. Characteristics and Outcomes of Patients Admitted to the ICU from Hospital Wards Pre- and Post-Rapid Response Team Implementation

	All ICU Admissions			Admissions Post-cardiopulmonary Arrests
Variable	Pre-RRT ($n = 856$)	Post-RRT ($n = 1158$)	p	Pre-RRT ($n = 99$)
Age, mean ± SD, y	59.2 ± 19.2	59.0 ± 19.0	0.84	63.0 ± 17.0
Women, n (%)	401 (46.9)	527 (45.5)	0.55	39 (39.4)
APACHE II score, mean ± SD	29.3 ± 9.3	26.9 ± 8.5	< 0.0001	35.9 ± 8.2
Main reason for admission, n (%)				
Respiratory	240 (28)	317 (27.4)	0.87	
Cardiovascular	470 (54.9)	636 (54.9)		
Neurologic	73 (8.5)	112 (9.7)		
Other medical	55 (6.4)	65 (5.6)		
Nonoperative	3 (0.4)	3 (0.3)		
Postoperative	15 (1.8)	25 (2.2)		
Chronic health points, n (%)				
Chronic liver disease	169 (19.8)	192 (17.2)	0.15	16 (16.2)
Chronic cardiovascular disease	411 (48.1)	302 (26.9)	< 0.0001	74 (74.8)
Chronic respiratory disease	398 (46.6)	147 (13.2)	< 0.0001	40 (40.4)
Chronic renal disease	306 (35.8)	220 (19.7)	< 0.0001	43 (43.4)
Chronic immunocompromised	147 (17.2)	179 (16.0)	0.49	14 (14.1)
Predicted mortality, mean ± SD				
MPM II_0	0.54 ± 0.31	0.42 ± 0.30	< 0.0001	0.83 ± 0.18
APACHE II	0.62 ± 0.26	0.57 ± 0.25	0.002	0.84 ± 0.15
Physiologic and clinical characteristics on ICU admission, n (%)				
Coma	402 (47.0)	317 (27.4)	< 0.0001	94 (95.0)
Severe tachycardia	66 (7.7)	40 (3.5)	< 0.0001	13 (13.1)
Hypotension	409 (47.8)	305 (26.4)	< 0.0001	69 (69.7)
Acute kidney injury	194 (22.7)	274 (23.7)	0.59	20 (20.2)
Mechanical ventilation	659 (77.0)	763 (66.0)	< 0.0001	99 (100.0)
Do-not-resuscitate order written during ICU stay				
n (%)	261 (30.5)	302 (26.1)	0.03	48 (48.5)
Relative risk (95% confidence interval)	0.86 (0.74–0.99)			1.01 (0.75–1.37)
Cardiopulmonary arrests in the ICU				
n (%)	53 (6.2)	46 (4.0)	0.02	14 (14.1)
Relative risk (95% confidence interval)	0.64 (0.43–0.96)			0.92 (0.43–1.95)

		Admissions Without Cardiopulmonary Arrests		
Post-RRT ($n = 108$)	p	Pre-RRT ($n = 757$)	Post-RRT ($n = 1050$)	p
64.2 ± 16.6	0.60	58.7 ± 19.4	58.5 ± 19.2	0.81
43 (39.8)	0.95	362 (47.8)	484 (46.1)	0.47
35.3 ± 8.5	0.70	28.5 ± 9.1	26.1 ± 8.1	< 0.0001
		240 (31.7)	317 (30.2)	0.83
		371 (49.0)	528 (50.3)	
		73 (9.6)	112 (10.7)	
		55 (7.3)	65 (6.2)	
		3 (0.4)	3 (0.3)	
		15 (2.0)	25 (2.4)	
10 (9.8)	0.18	153 (20.2)	182 (18.0)	0.23
44 (41.9)	< 0.0001	337 (44.6)	258 (25.3)	< 0.0001
8 (7.8)	< 0.0001	358 (47.4)	139 (13.8)	< 0.0001
36 (35.0)	0.22	263 (34.8)	184 (18.1)	< 0.0001
6 (5.8)	0.05	133 (17.6)	173 (17.1)	0.78
0.74 ± 0.22	0.001	0.50 ± 0.30	0.39 ± 0.29	< 0.0001
0.83 ± 0.17	0.81	0.60 ± 0.26	0.55 ± 0.25	0.002
88 (81.5)	0.003	308 (40.7)	229 (21.8)	< 0.0001
3 (2.8)	0.005	53 (7.0)	37 (3.5)	0.0008
41 (38.0)	< 0.0001	340 (45.0)	264 (25.2)	< 0.0001
28 (25.9)	0.33	174 (23.0)	246 (23.5)	0.82
104 (96.3)	0.05	560 (74.0)	659 (62.8)	< 0.0001
53 (49.1)	0.93	213 (28.1)	249 (23.7)	0.005
		0.80 (0.68–0.94)		
14 (13.0)	0.80	39 (5.2)	32 (3.1)	0.02
		0.59 (0.37–0.96)		

(*Continued*)

TABLE 3. (***Continued***) **Characteristics and Outcomes of Patients Admitted to the ICU from Hospital Wards Pre- and Post-Rapid Response Team Implementation**

	All ICU Admissions			Admissions Post-cardiopulmonary Arrests
Variable	Pre-RRT ($n = 856$)	Post-RRT ($n = 1158$)	p	Pre-RRT ($n = 99$)
Tracheostomy				
n (%)	141 (16.5)	151 (13.0)	0.03	24 (24.2)
Relative risk (95% confidence interval)	0.79 (0.64–0.99)			0.50 (0.25–0.96)
Mechanical ventilation duration, mean ± SD, d	8.7 (21.4)	6.3 (9.0)	0.002	7.6 (8.5)
ICU LOS, mean ± SD, d	9.9±22.1	8.0±9.3	0.02	7.2±8.3
Hospital LOS, mean ± SD, d	61.9±93.3	64.9±96.1	0.49	51.8±65.2
ICU mortality				
n (%)	302 (35.3)	362 (31.3)	0.06	54 (54.6)
Relative risk (95% confidence interval)	0.89 (0.78–1.01)			1.04 (0.80–1.35)
Hospital mortality				
n (%)	491 (57.4)	564 (48.7)	< 0.0001	77 (77.8)
Relative risk (95% confidence interval)	0.85 (0.78–0.92)			0.91 (0.77–1.08)
Standardized mortality ratio				
MPM II_0 (95% confidence interval)	1.06 (1.00–1.12)	1.16 (1.09–1.23)		0.94 (0.83–1.02)
APACHE II (95% confidence interval)	0.93 (0.87–0.98)	0.85 (0.80–0.91)		0.93 (0.82–1.01)

APACHE = Acute Physiology and Chronic Health Evaluation; MPM = Mortality Prediction Model; LOS = length of stay.

mechanical ventilation. In addition, there was a significant decrease in the number of patients admitted with advanced chronic cardiac, respiratory, renal, and liver diseases. The number of cardiopulmonary arrests for patients admitted from wards to the ICU also decreased. After RRT implementation, the mechanical ventilation duration and ICU LOS decreased. More importantly, hospital mortality for patients admitted to the ICU decreased from 57.4% to 48.7% (RR 0.85; 95% CI 0.78–0.92; $p < 0.0001$). The effect was consistent across all admitting services (data not shown). To examine whether these observed changes could be solely related to the reduction in postcardiopulmonary arrest admissions, we carried out stratified analysis (Table 3), which showed reduction in severity of illness and in mortality in patients admitted without cardiopulmonary arrests. SMR did not change after RRT implementation.

RRT Impact on DNR Orders

After RRT implementation, DNR orders initiated by the ICU team on the wards increased from 0.7 to 1.7 per 1,000 hospital admissions (RR 2.58; 95% CI 1.95–3.42; $p < 0.0001$) (Table 2) while DNR orders written in the ICU for patients admitted from the wards decreased from 30.5% to 26.1% (RR 0.86; 95% CI 0.74–0.99; $p = 0.03$) (Table 3).

RRT Impact on Post-ICU Outcomes

After RRT implementation, ICU readmission rate decreased from 18.6 to 14.3 per 100 alive discharges (RR 0.77; 95% CI 0.66–0.89; $p < 0.0001$) and post-ICU hospital mortality from 18.2% to 14.8% (RR 0.85; 95% CI 0.72–0.99; $p = 0.04$; **Table 4**).

Hospital Population Patient Mix

Between the two periods, there was no difference in APACHE II scores for non-RRT admissions to ICU from the operating room (20.3 ± 8.5 vs. 19.9 ± 8.3, $p = 0.44$) or emergency department (22.9 ± 9.1 vs. 22.7 ± 8.9, $p = 0.76$) neither there was a difference in hospital mortality (17.4% vs. 17.8%, $p = 0.85$ and 34.3% vs. 37.2%, $p = 0.32$, respectively).

		Admissions Without Cardiopulmonary Arrests		
Post-RRT ($n = 108$)	p	Pre-RRT ($n = 757$)	Post-RRT ($n = 1050$)	p
13 (12.0)	0.03	117 (15.5)	138 (13.1)	0.16
		0.85 (0.67–1.08)		
7.8 (9.5)	0.88	8.9 (22.5)	6.2 (8.9)	0.002
7.7 ± 9.6)	0.65	10.2 ± 23.3)	8.0 ± 9.4)	0.01
65.0 ± 88.9	0.23	63.2 ± 96.4	64.9 ± 96.9	0.72
61 (56.5)	0.78	248 (32.8)	301 (28.7)	0.06
		0.88 (0.76–1.01)		
76 (70.4)	0.23	414 (54.7)	488 (46.5)	0.001
		0.85 (0.77–0.93)		
0.95 (0.83–1.06)		1.09 (1.02–1.16)	1.19 (1.12–1.27)	
0.85 (0.74–0.94)		0.91 (0.85–0.97)	0.85 (0.79–0.90)	

TABLE 4. Post-ICU Outcomes Pre- and Post-Rapid Response Team Implementation

	Pre-RRT		Post-RRT	p
Alive discharges from critical care units	1485		2363	
ICU readmissions				
n (rate per 100 alive discharges)	276 (18.6)		338 (14.3)	< 0.0001
Relative risk (95% confidence interval)		0.77 (0.66–0.89)		
ICU readmissions within 48 hrs				
n (rate per 100 alive discharges)	43 (2.9)		56 (2.4)	0.32
Relative risk (95% confidence interval)		0.82 (0.54–1.24)		
Post-ICU hospital mortality				
n (%)	232 (18.2)		312 (14.8)	0.04
Relative risk (95% confidence interval)		0.85 (0.72–0.99)		
Post-ICU hospital stay, mean ± SD, d	40.3 ± 82.5		39.4 ± 70.3	0.75

RRT = rapid response team.

DISCUSSION

Our study demonstrates that an intensivist-led multidisciplinary extended RRT implementation improved the outcomes of acutely ill patients in the pre-ICU, within ICU, and post-ICU settings. For patients on the hospital wards, RRT implementation was associated with reductions in non-ICU cardiopulmonary arrests, transfers to the ICU, and mortality. In addition, it facilitated end-of-life discussions as reflected by the increase of DNR orders initiated by the team. For those patients who were admitted from the wards to the ICU, RRT implementation was associated with reduction in severity of illness and the presence of advanced chronic illnesses and reduction in the rate of DNR and codes in the ICU, need for tracheostomy, duration of mechanical ventilation and ICU LOS and most importantly, mortality. Furthermore, RRT reduced readmissions to the ICU and post-ICU mortality. These findings were likely related to RRT because there were no changes in hospital care processes or population patient mix as confirmed by similar severity of illness and mortality for non-RRT patients.

Our study also highlights certain points that may have contributed to the favorable outcomes. RRT enhanced the culture of safety, as reflected by empowering the ward nurses to initiate a majority of the activations (61.8%) and by activating the RRT even when they only have concern about a patient (23.1% of activations). Furthermore, the response to deteriorating patients on the floor was quick (median 5 mins). Also, early assessment of the team allowed timely discussion of patients' preferences regarding end-of-life care as shown by the increased DNR orders initiated by ICU service on the wards. The associated decrease in DNR orders in the ICU suggests that RRT reduced the subjection of patients with advanced chronic diseases to futile care. These decisions were appropriate because the total ward deaths did not increase, but actually decreased. Additionally, by providing post-ICU follow-up, RRT reduced readmissions and post-ICU mortality. These aspects of RRT implementation greatly facilitate the realization of the six aims of the IOM for quality improvement: patient safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity resulting in improved hospital outcomes (17).

Studies evaluating RRT effectiveness have revealed mixed results (8, 18–25). The Medical Early Response Intervention and Therapy (MERIT) trial (7) and a systematic review (10), the highest available evidence on the hierarchy of evidence-based medicine, did not show benefit from RRT. The variability of observed RRT benefit may be related to one of two categories of reasons. It may be a reflection of true differences in RRT effectiveness in different settings or a reflection of methodological differences in the study designs and outcome measurement tools.

The success of an RRT which is a complex intervention in a hospital, which in turn is a complex adaptive social system, depends on the complex interaction of multiple factors. This could explain the mixed results regarding RRT effectiveness. As such, differences in the reported effectiveness among different RRTs may be related to differences in the institutions, RRT implementation processes and RRT structure. First, at institutional level, leadership involvement is a key for success in change management. Additionally, the successful RRT implementation requires the buy-in of hospital staff and significant cultural changes. This is supported by a survey that suggested that the academic medical centers with successful RRTs defined each call as a chance to save a life as well as an educational opportunity to increase the knowledge of nurses, interns, and residents throughout the institution (26). Additionally, several studies showed that the number of calls influenced RRT efficacy: the higher the number of calls, the lower the cardiopulmonary arrest rate and unexpected deaths confirming the importance of early review of acutely ill ward patients by an RRT (27, 28). If ward nurses or physicians interpreted calling RRT as a sign of weakness, this may translate into decreased RRT effectiveness. Unlike our experience, cultural changes took time in some institutions implementing RRTs. Santamaria et al (5) found that it was not until 4 yr after the study that statistically significant changes in cardiopulmonary arrests and mortality rates were noted.

Second, the implementation process itself is critical. The Agency for Healthcare Research and Quality highlighted the steps for change (TeamSTEPPS) (29). These steps include creating sense of urgency, building the guiding team, developing a change in vision and strategy, understanding and buy-in, empowering others, achieving "short-term wins," "not letting-up," and creation of a new culture. The structured process of implementing our RRT followed these steps.

Third, the structure of the RRT system is very important. A recent review of RRT studies suggested that inclusion of a physician in the team was an important determinant of its effectiveness (28). Our multidisciplinary team was led by a dedicated intensivist reflecting the importance of engaging physicians in quality improvement projects as recommended by the IHI (30). Although there is a considerable controversy about the best activation criteria to identify patients at risk of cardiopulmonary arrest and death (6,31), the use of physiology-based activation criteria, like ours, has been recommended (13). Nevertheless, the "worried" criterion has been considered as a sign of a high degree of empowerment and independent action by nursing staff (32), which was the case in 23% of our activations.

Methodological differences in the study designs and outcome measurement tools may also affect the reported differences in RRT outcomes. The existing studies on RRT ignited a great debate about the applicability of evidence-based medicine hierarchy for interventions involving complex social adaptive systems (33). In such settings, it has been suggested that randomized, controlled trials which are considered traditionally to be the epitome of evidence-based medicine can be difficult to conduct and may miss important intervention effects (33). Related to this is the MERIT trial, a cluster randomized, controlled trial conducted in 23 Australian hospitals and compared RRTs to standard practice. The trial found no impact on the incidence of in-hospital cardiopulmonary arrests, unplanned ICU admissions, and unexpected deaths (7). The trial, despite its robust design, highlighted multiple issues that may have contributed to its inability to show a significant RRT effect. Reflecting the complexity of interventions in complex social adaptive systems, RRT implementation was not as complete and consistent as planned in the experimental hospitals. RRTs were activated for only 30% of patients who had physiologic deterioration according to RRT activation criteria (7, 13). Maintaining clear separation between the two hospital groups was not easy as reflected by the implementation of RRTs by the control teaching hospitals (7, 13). Additionally, the trial had low power to detect improvements by RRT because there were fewer events than expected and greater interinstitutional variability in event rates than anticipated when the trial was designed (13).

The most common interventions by the RRT on the wards were the administration of intravenous fluids, diuretics, tracheal suctioning, oxygen supplementation, and bronchodilator therapy and less commonly invasive interventions, such as endotracheal intubation and central venous catheter placement. This was related, in part, to the fact that patients who required these invasive interventions were usually transferred to the ICU first for a better setting unless the clinical condition mandates performing these procedures before transfer. However, these data also demonstrate that timely administration of "simple" interventions was what needed to prevent clinical deterioration in many patients; a task that RRT was designed for and qualified to deliver.

Our results should be interpreted in light of the study strengths and limitations. Strengths include the comprehensive evaluation of pre-ICU, ICU, post-ICU settings, the prospective data collection, and the sample size. Limitations include being a single-center study. Additionally, we did not analyze the compliance of ward staff with RRT activation protocol; a factor that has been shown to influence outcomes (34).

In conclusion, the implementation of an intensivist-led extended RRT was associated with reducing cardiopulmonary arrests and mortality for the ward patients, improving the outcomes of patients who needed ICU admission, and reducing readmissions and mortality of patients who were discharged from the ICU.

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