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Effects of a Rapid Response System Adjusted for Hospitals Prone to Afferent Limb Failure: A Practical Way to Reduce Unexpected Adverse Events

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Abstract

Aim: To evaluate effects of a modified Rapid Response System (RSS), management protocol, and education program in a Japanese university hospital where the conventional Medical Emergency Team (MET) interventions are not frequently activated.

Methods: We conducted a retrospective single-center cohort study of all cases requiring MET calls in the 2 years periods before and after the implementation period in 2015.

Results: MET calls were made for 52 patients per two years in the pre and 63 patients in the post-implementation period (1.34, 1.51 per 1000 admissions; RR 1.13, 95% CI 0.79 to 1.63, p=0.52), including 38 and 35 Unexpected Cardiac Arrest (UCA) cases (0.98, 0.84 per 1000 admissions; RR 0.86, 95% CI 0.54 to 1.36, p=0.56), and 14 and 28 non-cardiac arrests (0.36, 0.67 per 1000 hospital admissions; RR 1.87, 95% CI 0.98 to 3.55, p=0.06), respectively. The rate of MET calls for non CA increased by approximately twice. All unplanned ICU admissions significantly increased from 6.73 to 8.15 per 1000 admissions (RR 1.2, 95% CI 1.03 to 1.42, p=0.02). Twenty-eight-day mortality rates of MET call patients were 55% *vs*. 69% (pre *vs*. post; RR 1.57, 95% CI 1.132 to 3.198, p=0.025) for UCA and 29% *vs*. 29% for non-CA.

Conclusion: Based on the increased MET calls for non-CA, the modified safety net we introduced appeared to help improve afferent limb failure. The hospitals where cultural and behavioral barriers associated with inter-professional hierarchies also remain should establish and evaluate modified safety nets according to each hospital's actual situation.

Keywords: Intensive care unit; Rapid response team; Medical emergency team; In-hospital cardiac arrest; Psychological safety

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Abbreviations

ALF: Afferent Limb Failure; CI: Confidence Interval; ICUs: Intensive Care Units; JCQHC: Japan Council for Quality Health Care; MERIT: Medical Early Response Intervention and Therapy; METs: Medical Emergency Teams; RR: Relative Risk; RRS: Rapid Response System; RRTs: Rapid Response Teams; SAEs: Serious Adverse Events; UCA: Unexpected Cardiac Arrest

Introduction

Rapid Response Teams (RRTs) or Medical Emergency Teams (METs) have been implemented widely across both U.S. [1] and Japanese Hospitals [2] to identify patients at risk of deterioration and reduce unexpected Serious Adverse Events (SAEs) including cardiac arrest. In 2017, the Japan Council for Quality Health Care (JCQHC), a third party organization that evaluates medical institutions in Japan, added "having or not a system for identifying deteriorating patients" as one of its evaluation items. To pass this criterion, hospitals in Japan are urged to introduce some sort of Rapid Response System (RRS).

The effectiveness of RRT/METs is, however, controversial Although meta-analyses have reported decreased rates of cardiac arrest outside Intensive Care Units (ICUs) after the implementation of

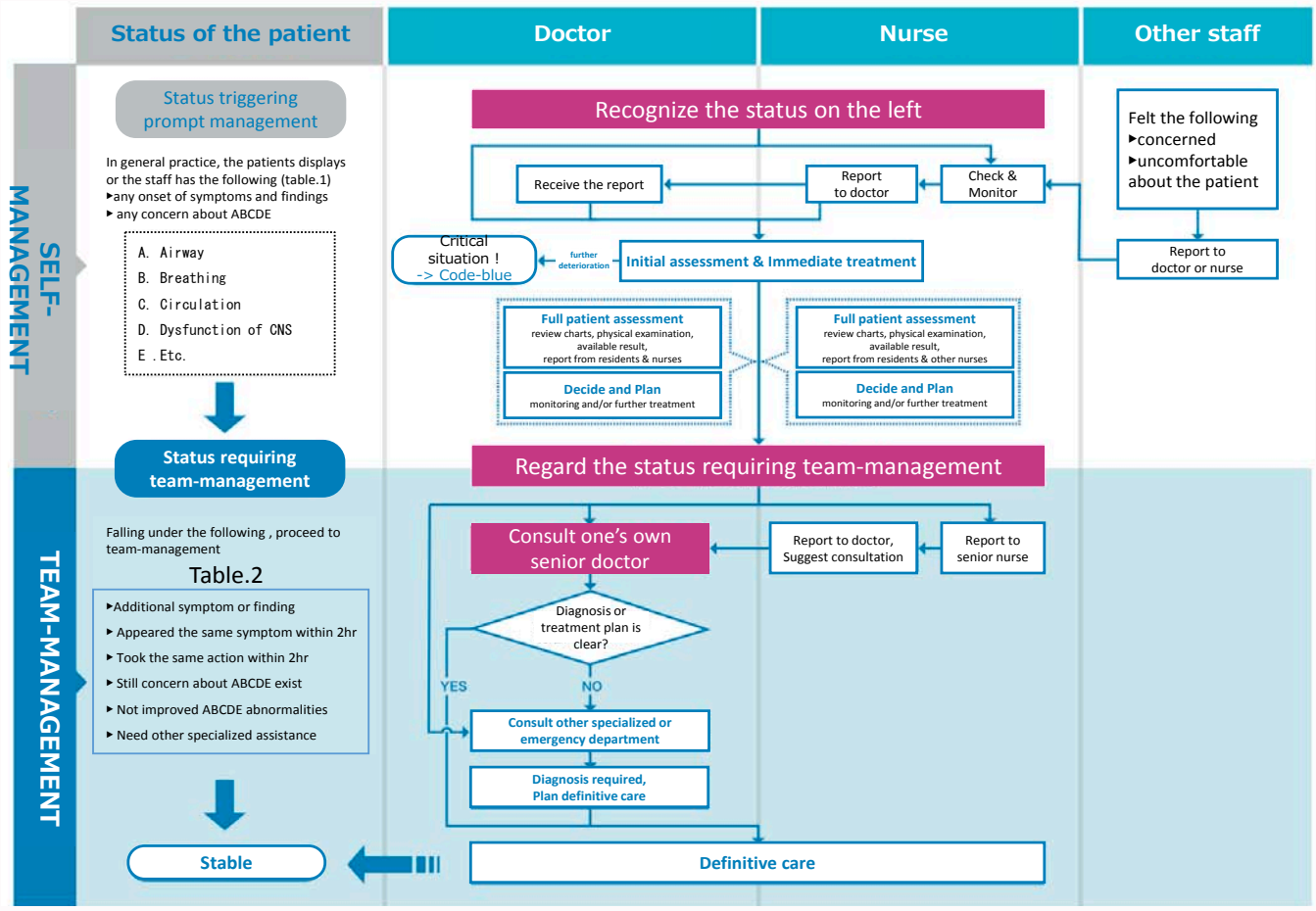

Figure 1: Resource management flow chart for doctors and nurses in non critical wards.

RRT/METs [3,4], robust evidence to support their effectiveness in reducing hospital mortality has not been reported [5]. The only cluster randomized controlled study, the Medical Early Response Intervention and Therapy (MERIT) trial, did not demonstrate decreased rates of cardiac arrest and mortality [6]. One of the reasons advocated explaining this result is "Afferent Limb Failure" (ALF). The RRS is composed of an afferent and efferent limb. The detection of at-risk patients and early RRT/METs activation for them by using a set of predetermined criteria constitutes the afferent limb of a RRS [7]. The study reported that the MET was called for only 30% of patients who fulfilled the calling criteria and were subsequently admitted to the ICU. An inverse relationship between such ALF and unexpected death and SAEs in RRT/MET hospitals has recently been suggested [8-11].

Making the potential benefits of RRS unclear, ALF might be a considerably larger problem in Japanese Hospitals, where ownership of patient care is still high, and each department may have their seriously ill patients in the ICU. Another significant barrier preventing full implementation of RRS in Japan is the lack of human resources for RRT/MET professionals. The OECD (Organization for Economic Co-operation and Development) Health Statistics 2016 showed Japanese hospitals have fewer doctors (18.5 per 100 beds) than other OECD countries [12], and there are too few nurses who can act as a member of a RRT/MET in Japan. Thus, it is difficult to recruit full time RRT/MET members and expect as many of their interventions as suggested to be effective.

Accordingly, when we started a modified RRS in place of a conventional cardiac arrest team-based system in 2015, we also launched an education program to break barriers of ALF and to improve the quality of care provided by the doctors and nurses who detected deteriorating patients, aiming to prevent unexpected SAEs by the system not depending on so many RRT/MET interventions. This study evaluated the effect of this attempt by analyzing the rates of unexpected cardiac arrest and RRT/MET calls before and after the implementation.

Methods

Clinical setting

Osaka City University Hospital has 980 beds, admits over 20,000 patients annually, and employs approximately 500 full-time doctors. The code blue system has been in place mainly for responding to cardiac arrests since before 2014. The MET for code-blue calls consisted of doctors and nurses working in the tertiary medical emergency center. In 2014, a working group in this academic hospital investigated the cases of SAEs during a 30 months period and revealed that in about 40%, antecedents had been observed prior to severe deterioration.

Implementation of RRS and education program

In 2015, we introduced a RRS comprising the same members of the conventional MET who are on call 24 h/d, 7 d/wk. In addition, are source management flow charts for doctors and nurses in non-critical wards (Figure 1) were prepared. The flowchart indicates that

Table 1: Criteria #1.

In general practice, the patient shows or the staff have observed the following: 1. Any onset of new symptoms and findings 2. Any concerns regarding ABCDE	
Airway	Obstructed
	Stridor
	Retractive breathing
	Excessive secretions
Breathing	Orthopnea
	Accessory muscles used
	Respiratory rate <10/min or >25/min
	SpO_2<93%
Circulation	Heart rate <50/min or >120/min
	Systolic blood pressure <90 mmHg or >180 mmHg
	Diastolic blood pressure >120 mmHg
	Shock index >1
	Urine output <50 mL in 4 h
Dysfunction of CNS	Acute change of mental status
	Agitated or delirious
Etc.	New pain
	New uncontrollable bleeding anywhere
	New unilaterality or numbness of limbs

the doctors and nurses in general wards should perform a "self-management" response to detect antecedents early, assess acutely, and act effectively when any objective warning criteria #1 (Table 1) are identified in the patients. Furthermore, by following "team-management", staff members are strongly encouraged to speak up to their senior staff and/or call the MET when any of criteria #2 are fulfilled such as 1) the presence of any additional symptoms or findings, 2) appearance of the same symptom within 2 h, 3) taking the same action within 2 h, 4) concerns about ABCDE still remain, 5) no improvement of criteria #1 abnormalities, and 6) the need other specialized assistance.

As well as regular lectures aimed at introducing this management flow chart, we started staff education to enhance the adherence to this response. Especially, a simulation training course, called Early Awareness and Rapid Response Training in Hospitals (EARRTH), was held monthly to teach young doctors and nurses how to use this system. To avoid delays in MET calls, we recommended self-management performance prior to MET activation. Furthermore, we implemented a monthly scenario-based training aimed at improving self-management quickly and effectively and moving easily to team-management that includes calling the MET.

Subjects, data collection, and definitions

The patients in the adult general wards who required a MET call in the 2 years periods before and after the implementation were selected. A retrospective review of the medical records and data of these patients was carried out. The pre-period and post-period were defined to extend from April 2013 to March 2015 and from April 2016 to March 2018, respectively.

As suggested by the Utstein-style scientific statement, we analyzed the MET call cases by reviewing their medical charts. We compared the numbers of Unexpected Cardiac Arrest (UCA) between both periods and the existence and timing of the documented physiological instability of the patients as defined by criteria #1 in the period of 10 min to 24 h prior to the UCA. "Do not attempt resuscitation" cases were excluded.

Statistical analyses

Categorical variables were compared with the chi-square test or Fisher's exact test, and continuous variables were compared with the Mann–Whitney U test. A p-value <0.05 was considered statistically significant. Statistical analysis was carried out using EZR [13], which is a graphical user interface for R. More precisely, it is a modified version of R commander designed to add statistical functions frequently used in biostatistics.

Results

MET call cases

The total numbers of MET calls in each period were 52 and 63 (1.34 and 1.51 per 1000 admissions, Relative Risk [RR] =1.13, 95% Confidence Interval [CI] 0.79 to 1.63, p=0.52), including 38 and 35 UCA cases (0.98 and 0.84 per 1000 admissions, RR=0.86, 95% CI 0.54 to 1.36, p=0.56), and 14 and 28 non-cardiac arrests (0.36 and 0.67 per 1000 admissions, RR=1.87, 95% CI 0.98 to 3.55, p=0.06), respectively (Table 2).

Mortality of UCA cases

Those with UCA in the post-period were more likely to have a lower prevalence of Return of Spontaneous Circulation (ROSC) (34/38 [89%] *vs.* 20/35 [57%], pre *vs.* post; RR=0.64, 95% CI 0.530 to 0.844, p<0.01). The 28 days mortality rates of MET call cases for UCA were 55% *vs.* 69% (pre *vs.* post; RR=1.57, 95% CI 1.132 to 3.198, p=0.025) (Table 3).

Documented criteria prior to cardiac arrest

Most patients arrested between 8:30 AM to 5 PM in the pre-period (39%) but between 1 AM to 9 AM in the post-period (51%) (Table 3). There was some sort of documentation of criteria #1 in the period from 10 min to 24 h prior to a UCA for 19 (50%) patients in the pre-period *vs.* for 23 (66%) patients in the post-period (Table 4). In the post-period, the clinical antecedents in 10 (43%) patients occurred during the day time. The time to documentation of an antecedent prior to an event was mostly 4 h to 8 h (5 cases, 26%) in the pre-period but was 16 h to 20 h (6 cases, 26%) in the post-period (Table 4, Figure 2). Some interventions were performed in 15 (79%) and 18 (78%) patients, respectively, after the observation of deterioration.

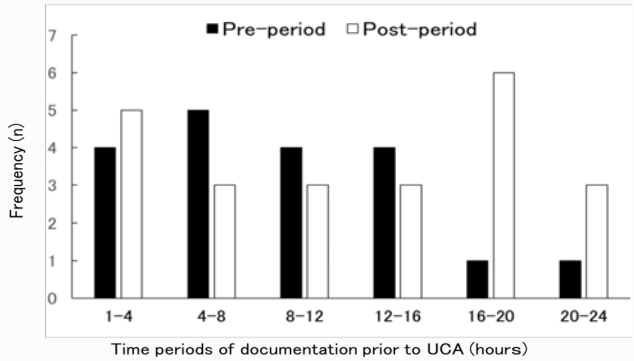

Figure 2: Occurrence of UCA with documentation of criteria #1 prior to UCA for each period.

Table 2: Patient characteristics.

	MET Call		
	Pre-period (n=52 [1.34])	**Post-period (n=63 [1.51])**	**p-value p=0.519**
For unexpected cardiac arrest	38 (73%)	35 (56%)	
	[0.98]	[0.84]	p=0.559
Male sex	27 (71%)	22 (63%)	p=0.621
Age, mean ± SD	68.5 ± 15.5	66 ± 15.7	p=0.407
For non-cardiac arrest	14 (27%)	28 (44%)	
	[0.36]	[0.67]	p=0.06
Male sex	7 (50%)	14 (50%)	p=1
Age, mean ± SD	57.1 ± 20.6	64.7 ± 16.0	p=0.24
Reason for call			
Airway threatened	1 (7%)	0 (0%)	p=0.439
Respiratory problem	6 (43%)	12 (43%)	
Hemodynamic abnormality	5 (36%)	11 (39%)	
Neurologic derangement	4 (29%)	16 (57%)	
Other	3 (21%)	4 (14%)	

MET: Medical Emergency Team [per 1000 admissions]

Table 3: Twenty-eight-day mortality rate of MET call cases for UCA.

	MET Call for UCA				
	Pre-period (n=38 [0.98])		**Post-period (n=35 [0.84])**		**p-value**
Time period of arrest					
Daytime (8:30 AM to 4:59 PM)	15	(39%)	12	(34%)	p=0.277
Night 1 (5 PM to 0:59 AM)	10	(26%)	5	(14%)	
Night 2 (1 AM to 8:29 AM)	13	(34%)	18	(51%)	
Daytime on weekdays	9	(24%)	7	(20%)	p=0.782
Night and weekends	29	(76%)	28	(80%)	
Witnessed arrest	29	(76%)	27	(77%)	p=1.0
Initial cardiac arrest rhythm					
Asystole	6	(16%)	12	(34%)	p=0.336
Pulseless electrical activity	12	(32%)	10	(29%)	
Vf/Pulseless VT	8	(21%)	5	(14%)	
Other/unknown	12	(32%)	8	(23%)	
ROSC	34	(89%)	20	(57%)	p=0.003¶
Mortality					
24-hours	12	(32%)	21	(60%)	p=0.015
7-days	16	(42%)	23	(66%)	p=0.043
28-days	21	(55%)	24	(69%)	p=0.025

MET: Medical Emergency Team; ROSC: Return of Spontaneous Circulation; UCA: Unexpected Cardiac Arrest [per 1000 admissions] ¶Fisher's exact test

MET calls for non-cardiac arrest

Table 5 shows the reasons for MET activation and outcomes of the non-cardiac arrest patients. Fifty percent of the patients were transferred to the ICU in the post-period, compared to 36% in the pre-period. The 28 days mortality rates were 29% in both periods.

Unplanned ICU admissions

After the implementation, the number of unplanned ICU admissions increased significantly from 6.73 to 8.15 per 1000 admissions (RR 1.2, 95% CI 1.03 to 1.42, p=0.02) (Table 6). Within these cases, the numbers of the patients admitted following a MET call were similar between both periods (pre 0.67 *vs.* post 0.67 per 1000 admissions, RR=1.0, 95% CI 0.59 to 1.70, p=1). The proportion of cases following a MET call for non-cardiac arrest also increased significantly (pre-period 19% *vs.* post-period 50%, RR=2.60, 95% CI 1.17 to 6.24, p=0.024).

Discussion

In 2014, a working party in our hospital investigated successive code blue cases during a 30 months period. They revealed that 10 of 94 (11%) cases were avoidable if antecedents prior to severe deterioration had been promptly identified and adequately treated. Those cases had two features: 1) the inability to assess antecedents-although most staff had been aware of the symptoms or signs, they

Table 4: Documented criteria #1 and following treatment action.

	MET Call for UCA		
	Pre-period (n=38)	**Post-period (n=35)**	**p-value**
Documented criteria #1 within 10 min to 24 h prior to UCA	19 (50%)	23 (66%)	p=0.237
Time period of documentation			
Daytime (8:30 AM to 4:59 PM)	4 (21%)	10 (43%)	p=0.391
Evening (5 PM to 0:59 AM)	8 (42%)	6 (26%)	
Night (1 AM to 8:29 AM)	7 (37%)	7 (30%)	
Daytime on weekdays	2 (11%)	7 (30%)	p=0.149
Time of documentation prior to UCA			
Median, minutes	525 (IQ 284, 821)	776 (IQ 366, 1134)	p=0.28
10 min-4 h	4 (21%)	5 (22%)	
4-8 h	5 (26%)	3 (13%)	
8-12 h	4 (21%)	3 (13%)	
12-16 h	4 (21%)	3 (13%)	
16-20 h	1 (5%)	6 (26%)	
20-24 h	1 (5%)	3 (13%)	
Treatment action after documentation			
Self and/or team	15 (79%)	18 (78%)	p=1.0
Nothing or unidentified	4 (21%)	5 (22%)	

MET: Medical Emergency Team; UCA: Unexpected Cardiac Arrest

Table 5: Reasons for MET activation and patient outcome.

	Met Call For Non-Cardiac Arrest		
	Pre-period (n=14 [0.36])	**Post-period (n=28 [0.67])**	**p-value p=0.06**
Reason for activation			
Airway threatened	1 (7%)	0 (0%)	p=0.439
Respiratory problem	6 (43%)	12 (43%)	
Hemodynamic abnormality	5 (36%)	11 (39%)	
Neurologic derangement	4 (29%)	16 (57%)	
Other	3 (21%)	4 (14%)	
Patient outcome			
Transferred to			
ICU	5 (36%)	14 (50%)	p=0.366
HCU	2 (14%)	1 (4%)	
Not transferred (general ward)	7 (50%)	13 (46%)	
Mortality			
24-hour	1 (7%)	4 (14%)	p=0.65
7-day	1 (7%)	6 (21%)	p=0.392
28-day	4 (29%)	8 (29%)	p=1.0¶

ECU: Emergency Care Unit; with MET: (Medical Emergency Team) support for care; HCU: High Care Unit without MET support [per 1000 admissions], ¶Fisher's exact test

could not assess them correctly, and 2) the absence of clear rules to speak up to their seniors-the junior staff did not promptly consult with their senior staff. These issues arose when young doctors, who are particularly third-year residents and tend to avoid asking seniors for help, were on night duty.

ALF is still a major issue even in well-established hospitals with a RRS. The causes of ALF area lack of recognition of the signs of deterioration and cultural and behavioral barriers associated with inter-professional hierarchies in the clinical area [14,15]. Fear of criticism was identified as an important barrier to activation of the MET [15,16], and these barriers are particularly common in junior and inexperienced ward staff members [17-19]. Removing the barriers is mainly a matter of education [17]. Moreover, as Davies et al. emphasized, current methods of staff education using lectures, orientation sessions, and posters are not sufficiently effective. An *in situ* simulation training program to familiarize staff with how to recognize critical patient deterioration, when and how to trigger the RRS, and how to hand off to the responder team, is needed [20,21].

Table 6: Unplanned ICU admissions.

	Unplanned ICU admission				
	Pre-period n=262	Post-period n=340	RR	95% CI	p-value
	[6.73]	[8.15]	1.217	1.032-1.423	p=0.019¶
MET call cases	26 [0.67]	28 [0.67]			
			1.006	0.594-1.705	p=1.0¶
for UCA	21 (81%)	14 (50%)			
	[0.54]	[0.34]	0.623	0.321-1.209	p=0.166¶
for non-UCA	5 (19%)	14 (50%)			
	[0.13]	[0.34]	2.615	0.980-6.977	p=0.066#

CI: Confidence Interval; ICU: Intensive Care Unit; MET: Medical Emergency Team; RR: Relative Risk, [per 1000 admissions]. ¶χ: square test; #Fisher's exact test

Given these circumstances, we have held the two education programs, 1) a monthly scenario-based training for young doctors and nurses since 2015, and 2) a number of educational lectures using an animated cartoon since 2016 [22]. In these sessions, the trainers taught how to detect antecedents of deteriorating patients earlier, explained that our hospital has a system in place for reporting and consultation without being criticized, and recommended participants to call the MET without hesitation, if they have any concerns. In the present study, the numbers of UCAs and unplanned ICU admissions were not reduced, but the rate of MET calls for non-CA increased by approximately two times, which is a most remarkable result. This two-fold increase occurred because the frequency of realizing antecedents increased and the burden of calling the MET was reduced.

The increase in the number of patients transferred to the ICU after MET calls should be interpreted carefully, however. The effect of the RRS on ICU admission rates remains uncertain [4,5]. In the MERIT study, no significant change was found in the number of unplanned ICU admissions between control and MET hospitals (4.68 *vs.* 4.19 per 1000 admissions) [6]. Unplanned ICU admissions showed a declining trend (before *vs.* after, 19.8 *vs.* 17.1 per 1000 admissions) in the multi-center study performed by Ludikhuize et al. [23]. O'Connell et al. [24] reported in a single-center, 6-year study that increased RRS call rates (1.7 calls per 10,000 hospital admissions per month) were associated with a decrease in unplanned ICU admissions (0.079 per 10,000 admissions per month). In contrast, the number of unplanned ICU admissions did not change (before *vs.* after, 5.0 *vs.* 5.9 per 1000 admissions) in a long-term analysis at a single center by Herod et al. [25] but increased in a cluster randomized controlled trial performed by Haegdorens et al. [26] (6.5 *vs.* 10.3 per 1000 admissions). In a review, Tirkkonen et al. [5] showed that in 5.3% to 56.5% RRS calls reviewed, 8.2% to 56% (median 23%) of them resulted in unplanned ICU admissions. Thus, ICU admission rates are difficult to interpret when studying the effectiveness of the RRS because admittance to the ICU is strongly dependent on different countries' policies, health care insurance systems, and local circumstances [27]. ICU admissions after MET calls for non-CA cases in the present study rose from 19% to 50%, which is comparable to the 49.4% reported by Kawaguchi et al. [28] in a single center with a RRS and the in-Hospital Emergency Registry in Japan report by Kurita et al. [29] (43.5% in the hospitals with low rates of RRS calls [median 1.6 calls per 1000 admissions]). Considering the factor of Japan's culture, the increase in the number of ICU admissions in the present study does not always indicate that the reason was SAEs. As an effect of our education program, patient deterioration was detected in a timelier manner, and more patients were transferred from the general wards, where the number of doctors and nurses is lower at night, to the ICU just for continuous monitoring and careful or effective treatment.

A significant reduction in the number of UCAs was not found, and rates of ROSC decreased significantly (pre 89% *vs.* post 57%) in the present study. Moreover, 28 days mortality rates after UCA increased (pre 55% *vs.* post 69%). According to the J-RCPR (Japanese Registry of CPR for in-Hospital Cardiac Arrest), which includes many hospitals specializing in cardiovascular disease, the rate of ROSC after cardiac arrest was 64.7%, and 30-day mortality rates were 72.2%. It is possible that in the post-period, potentially critical patients suffered cardiac arrest in the 16 h to 20 h after documentation despite having received required treatment in the general wards. Although their fatal deterioration could not necessarily be avoided, we have to take further action to save these patients. The fact that quite a few patients presented with some kind of abnormality initially in the daytime and went into cardiac arrest at midnight or before dawn indicates that the quality of care at night needs to be improved by enhancing MET interventions and strengthening the leadership and management skills of doctors and nurses in general wards to use the resources available in our hospital fully and effectively.

Conclusion

The safety net including the RRS and the education program that we introduced appeared to have contributed to the improvement of ALF. As Japanese hospitals have few doctors and nurses who can respond to MET calls for their beds, and cultural and behavioral barriers associated with inter-professional hierarchies also remain, it is important to establish safety nets and evaluate them in accordance with the actual situation at each hospital.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of the Osaka City University Hospital (2020-254). All patients received the standard care available at the hospital, and no subjects underwent any type of experimental intervention. The Ethics Committee approved this study and waived the need for oral or written consent.

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