Effectiveness and safety of an emergency department-based rapid response system

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Abstract

Rapid Response Systems (RRSs) are designed to assist hospitalized patients who become unstable, aiming to address "failure to rescue" and prevent cardiac arrests. Despite global implementation, evidence of RRS effectiveness is controversial. This study evaluates the effectiveness and safety of an RRS at Maggiore Hospital in Lodi, Italy, focusing on the Medical Emergency Team (MET) organization. The RRS at Maggiore Hospital was established in 2017 using the National Early Warning Score (NEWS) for monitoring. The MET, consisting of an emergency physician and one nurse, operates from 8:00 PM to 8:00 AM. Data from 2014-2019, divided into PRE (2014-2016) and POST (2017-2019) periods, were analyzed. The primary outcomes were unplanned ICU transfers and in-hospital mortality. A difference-in-differences (DiD) design compared outcomes in MET and non-MET wards before and after RRS implementation. Hospitalizations were similar in the PRE and POST periods. A significant reduction in Intensive Care Unit (ICU) transfers was observed overall (0.26%, p=0.005), but not in mortality (0.10%, p=0.47). Both MET and non-MET wards showed reduced ICU transfers, but the decrease was statistically significant only in MET wards. DiD analysis showed no significant reductions in either ICU transfer (p=0.77) or mortality rates (p=0.15) between MET and non-MET wards. The RRS at Maggiore Hospital effectively reduced ICU transfers without increasing mortality, demonstrating its safety. The MET organization did not significantly impact ICU transfers compared to non-MET wards. Further studies should explore additional measures of clinical deterioration to fully assess the impact of RRS.

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Introduction

Rapid Response Systems (RRSs) are created to assist patients hospitalized outside high-intensity care areas who become unstable during their stay.[1] The establishment of RRSs aims to address what is referred to in the literature as "failure to rescue", which is the failure to recognize early signs and symptoms of clinical instability in hospitalized patients, or delays in implementing procedures or therapies to prevent cardiac arrest.[2] Hemodynamic instability, especially in the early stages, alterations in consciousness, and uncontrolled pain are often not recognized as indicative of clinical deterioration, resulting in increased in-hospital mortality and unplanned admissions to the Intensive Care Unit (ICU), leading to extended hospitalization times and increased healthcare costs.[1,3]

Albeit heterogeneously organized, RRSs generally involve monitoring the deterioration of patients in general hospital wards and organizing a team of responders trained and equipped to intervene. Various names have been used in the literature to refer to such teams, including rapid response teams, patient-at-risk teams, critical care outreach teams and medical emergency teams.[4] Following the recommendations, we will refer to the team of physicians implemented in the RRS under study as Medical

Emergency Team (MET).[5] RRSs have been widely implemented globally, and different healthcare organizations (e.g., the Institute for Healthcare Improvement and the 2009 Joint Commission's National Safety Goal in the United States, and the National Institute of Clinical Excellence in the United Kingdom) have emphasized the need to establish intra-hospital RRSs and make them as efficient as possible.[6,7] The importance of preventing in-hospital cardiac arrest and, even more importantly, recognizing and correctly treating critically ill patients has also been highlighted by the European Resuscitation Council's Guidelines, which propose the concept of the "in-hospital survival chain".[2] This chain consists of five key items: staff education, patient monitoring, recognition of signs of clinical instability, notification to the MET of potential risks, and the team's response.

Despite the worldwide diffusion, evidence on the effectiveness of RRS on meaningful patient outcomes is controversial.[8] This study aims to evaluate the effectiveness and safety of implementing an RRS in the Maggiore Hospital in Lodi, Italy, and, within the broad RRS, assess the effectiveness and safety of the MET organization. Specifically, two organizational premises made the RRS implementation possible. The first was the implementation of the SIAARTI (Italian Society of Anesthesia, Analgesia, Resuscitation, and Intensive Care) – IRC (Italian Resuscitation Council) Recommendations for organizing responses to In-Hospital emergencies,[9] which consisted of standardizing criteria for responding to in-hospital cardiac arrest and unifying emergency carts. These actions were implemented in the Maggiore Hospital in Lodi in 2010. The second can be summarized as a profound revision of the operational mandate of the Emergency Department of Lodi, which transitioned from October 2014 and in the following years from a philosophy summarized as "admit to work" to a management characterized by the philosophy of "work to admit"[10] through the implementation of diagnostic tools such as integrated clinical ultrasound (POCUS) and the progressive inclusion (in the staff of the operational unit).

Materials and Methods

Setting

The Maggiore Hospital of Lodi is a hospital in northern Italy with approximately 300 beds. The hospital serves a catchment area of approximately 200,000 people and covers a mixed urban and rural territory. It features a general and pediatric emergency department, an intensive care unit, surgical departments (excluding neurosurgery) and specialized medical wards.

The emergency department admits approximately 60,000 patients each year.

Rapid Response System

The RRS of the Maggiore Hospital in Lodi, Italy, including the organization of the intra-hospital MET, was established through hospital protocols in 2017. The general monitoring framework is based on the National Early Warning Score (NEWS).[11-14] The score is computed by the nursing staff and evaluated following standard models for the temporal surveillance of patients. The frequency of the re-evaluations of the score and the responses associated with the values are provided in Table 1. In particular, the NEWS monitoring system is applied to i) all patients admitted to hospital wards between 8:00 PM and 8:00 AM; ii) patients for whom the attending physician has previously determined the need for NEWS assessment; iii) patients who, in the last 24 hours, underwent a surgical procedure, were transferred from Intensive Care Unit (ICU) or sub-intensive care units, or were the target of a MET intervention. End-stage patients and patients identified as not amenable to resuscitative treatment are excluded from NEWS monitoring.

The MET organized within this RRS consists of one emergency physician and one emergency nurse and is active from 8:00 PM to 8:00 AM. The MET physician is directly responsible for patients in the short-term observation unit and acts as the Emergency Department (ED) shift supervisor. The on-duty intensivist responds to specific calls from the emergency physician in cases of cardiac arrest, peri-arrest situations, or cases requiring airway management. The MET comprises emergency medicine physicians or physicians with related specialities with years of experience in the ED, assisted by nurses with extensive experience in the ED and ambulance services. The team has its own set of instruments, including a multidisciplinary ultrasound machine, and applies the same operational protocols for in-hospital emergencies as those used in the ED. Interventions of the MET are requested by the nursing staff and controlled by the monitored NEWS score (see Table 1) in the following departments: Multispecialty Surgery (vascular surgery, ENT, ophthalmology, urology), Internal Medicine, Pulmonology, Nephrology, Orthopedics, and Plastic Surgery. In departments where the specialist on-call is still active (General Surgery, Neurology, Gynecology), MET activation is coordinated by the attending on-call physician or is initiated directly by the nursing staff if the physician is engaged in another emergency or surgery. After assessing the patient and implementing a therapeutic strategy, the MET physician selects the most suitable area for managing the patient in terms of safety and patient's potential for intervention. Any transfer to the ICU is coordinated with the intensivist after a joint evaluation.

Endpoint

The primary outcome in evaluating the effectiveness of the RRS implementation and the MET organization was the number of

Table 1. Frequency of NEWS re-evaluations and actions to be implemented depending on the NEWS value in the implemented Rapid Response System.

NEWS Score	Frequency of Re-evaluation	Clinical response
0	At least every 12 hours	Re-evaluation of the score with the indicated frequency
1-4	At least every 6 hours	Re-evaluation of the score with the indicated frequency
≥5 or 3 in single item	At least hourly	The nurse alerts the MET. The MET physician urgently assesses the conditions of the patient. The adequacy of the care intensity level is evaluated.
≥7	Continuously	The nurse alerts the MET in emergency. The MET physician immediately assesses the patients conditions, possibly with the on-duty intensivist. Admission to semi-intensive or intensive care unit is considered.

unplanned transfers to the ICU from the general hospital wards. To evaluate the safety of the implemented programs, the outcome of interest was the number of in-hospital deaths of patients hospitalized in the general wards.

Data

Our analysis focused on the years preceding 2020, as the COVID-19 pandemic caused important organizational changes to the structure of the hospital and epidemiological changes to the admitted patients. As the RRS was implemented at the beginning of 2017, data were extracted from 2014 so that the time intervals before and after RRS activations were the same length (three years). The two disjoint time intervals are referred to as PRE (2014-2016) and POST (2017-2019).

We defined MET departments as those under the direct supervision of the MET physician, while we flagged the departments with an attending departmental physician as non-MET. In both groups, we extracted the total number of yearly admissions, unplanned ICU transfers, and in-hospital deaths from the administrative databases of the Maggiore Hospital and, specifically, from the Hospital Discharge Records. Patients hospitalized after ED visits and transferred to the ICU within 24 hours of hospitalization were considered direct ICU admissions. Admissions on different dates were categorized as post-admission transfers. In the case of multiple ICU transfers for the same patient (*e.g.*, surgical procedures or revisions), only the first transfer was counted. Departments not involved in the RRS, including all divisions of hospital facilities different from the Maggiore Hospital, the ICU and the Pediatrics department, were not included in the study.

The study only used aggregated data, which are anonymous. As anonymous data do not represent personal information, the study does not require ethics committee approval nor patient informed consent.[15]

Statistical analysis

To evaluate the effect of the RRS implementation, we compared the rate of ICU transfers and hospital mortality in the PRE and POST periods. Comparisons were performed overall and separately for MET and non-MET wards with a chi-squared analysis. Differences between PRE and POST periods were quantified as risk differences with a corresponding 95% confidence interval. We adopted a difference-in-difference design (DiD) to assess the effectiveness and safety of the MET interventions within the RRS. We computed the differences between the PRE and POST periods separately for MET and non-MET wards for both the rate of ICU transfers and mortality. In particular, if MET interventions effectively reduced unplanned ICU transfers, we expected a steeper PRE-POST decrease of ICU transfers in MET wards compared to non-MET wards. Similarly, if such interventions did not worsen the outcome of patients, we expected comparable PRE-POST changes in mortality in the two ward groups. We used a binary outcome regression model with identity link to perform these analyses. Both ICU transfer and mortality rate models included the ward type (MET or non-MET), the period (PRE or POST), and the interaction between these two variables. The coefficient of the interaction term provides an estimate of the difference between the two PRE-POST differences in MET and non-MET wards.

All the variables available for analysis were categorical and were described using counts and proportions. P-values less than 0.05 were considered statistically significant. The analyses were conducted with R, version 4.0.2.[16]

Results

The number of hospitalizations in the PRE and POST periods is provided in Table 2, both overall and separately for MET and non-MET wards. Hospitalizations in the two three-year periods were similar and equally distributed between MET and non-MET wards.

Table 2 also compares the number of unplanned transfers to ICU and deaths between the PRE and POST periods. Overall, the reduction in the rate of ICU transfers (PRE-POST difference: 0.26%; 95%CI: 0.08%, 0.45%) was significant (p-value=0.005), while there was no evidence of mortality difference between the two periods (PRE-POST difference: 0.10%; 95%CI: -0.16%, 0.36%; p-value=0.47). A reduction in ICU transfers was observed in both MET and non-MET wards, even though it did not reach statistical significance in non-MET wards (p-value: 0.09). Hospital mortality did not increase in either ward group; we observed a marginally significant reduction in mortality in non-MET wards (p-value: 0.04).

Figure 1 compares the yearly rate of unplanned ICU transfers separately for MET and non-MET wards. Overall, we observed a decreasing trend in ICU transfers in both groups starting from 2014 and, thus, before the implementation of the RRS. The DiD analysis compared the temporal changes observed in MET wards

Table 2. Number of hospitalized patients, unplanned transfers to ICU and deaths separately for the MET and non-MET wards and for the three-year periods before (PRE) and after (POST) the implementation of the Rapid Response System.

	PRE (2014-2016)	POST (2017-2019)	p[2]
Hospitalizations (N)			
MET wards	15,387	14,107	-
Non-MET wards	16,029	14,897	-
MET and non-MET wards	31,416	29,004	-
Transfers to ICU[1] – N (%)			
MET wards	242 (1.57%)	178 (1.26%)	0.028
Non-MET wards	210 (1.31%)	163 (1.09%)	0.092
MET and non-MET wards	452 (1.44%)	341 (1.18%)	0.005
Hospital deaths[1] – N (%)			
MET wards	585 (3.80%)	553 (3.92%)	0.62
Non-MET wards	257 (1.60%)	196 (1.32%)	0.040
MET and non-MET wards	842 (2.68%)	749 (2.58%)	0.47

[1] The proportion is computed using the corresponding number of hospitalizations as denominator. [2]Comparison of the proportion of ICU transfers and deaths between PRE and POST.

to those observed in non-MET wards and found that the two reductions in ICU transfers were not significantly different (p-value=0.77). In particular, the reduction of transfers in MET wards was 0.10% (95%CI: -0.73%, 0.54%) higher than in non-MET wards. The yearly mortality rates in MET and non-MET wards are provided in Figure 2. Again, the changes in mortality in MET and non-MET wards were not significantly different (p-value=0.15). In particular, mortality increased slightly in MET wards than in non-MET wards (0.41%; 95%CI: -0.14%, 0.95%).

Discussion

The study aimed to evaluate the effectiveness of the RRS implemented at the Maggiore Hospital in Lodi, Italy. With this goal, we analyzed unplanned ICU transfers and deaths in hospital wards before and after the implementation of the system. The analysis explored the possible differential effect in departments under the supervision of the MET, in charge of the ED, and departments where the RRS protocol involves the activation of a departmental physician.

The difference-in-difference analysis comparing the periods before and after the RRS implementation showed a downward trend in unplanned ICU transfers for both MET and non-MET departments. While the reduction observed in MET wards was greater, it did not reach statistical significance. Therefore, the organization of the response team did not appear to impact the volumes of unplanned ICU transfers significantly. On the other hand, the reduction of transfers in both groups of wards suggests that the overall monitoring framework with scoring systems (such as the NEWS in this case) may positively impact the hospital's functioning. This result is in line with previous observational studies[17-19] that have shown a reduction in ICU transfers after activating an RRS. Importantly, our study focused on unplanned ICU transfers to capture relevant deteriorations of patients hospitalized in ordinary wards. This is one of the most popular outcome measures that has been considered in the literature to assess the effectiveness of RRS, together with hospital mortality.[20] Other outcomes that may be more specific for clinical deteriorations are in-hospital cardiac arrest or mortality for cardiac arrest, as a proportion of the hospital deaths are planned. However, even though these outcomes may be more robust to assess the effectiveness of RRS, they are not easily extractable from routinely collected administrative data. Furthermore, all of these measures are poor indicators for evolutions that do not result in important organ failures. Future studies should assess whether establishing an RRS impacts other measures of clinical deterioration.

Importantly, the analysis of the yearly frequency of unplanned transfers to the ICU showed a clear reduction from the start of the study period and, thus, before the implementation of the RRS. This data should be considered in light of the broader actions that were put in place in the Maggiore Hospital over the study years, which included the standardization of the criteria for the response to in-hospital cardiac arrests and the alteration in the operational mandates of the ED, shifting to a "work to admit" from an "admit to work" approach. In particular, the change in prehospitalization protocols, which involves stabilizing the patients in the Emergency Room, may have impacted the volumes of unplanned ICU transfers from ordinary wards, as the timely start of treatments is associated with improved outcomes for time-dependent diseases.

Because the implementation of RRS may result in a reduction of ICU transfers that, in turn, may negatively impact patients' survival, our study verified the safety of the system by analyzing hospital mortality over time. We did not observe increased mortality rates, which is promising in view of a possible extension of the RRS through 24-hour patient monitoring with early warning scores. All in all, we believe that the positive outcomes can be credited to the overall management of the care pathway for patients admitted from the ED, as well as to the experience, skills, and equipment of the MET team. In our experience, the training of the MET staff in emergency care, the rigorous monitoring of the NEWS score and the precise criteria for MET activation were among the most important elements of the RRS.

Our study has limitations. Firstly, being a single-center study, its findings may not immediately apply to other hospitals. Since RRS must consider specific organizational and structural hospital

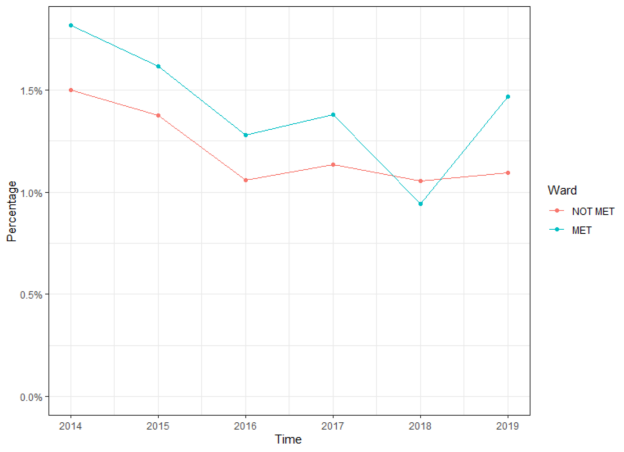

Figure 1. Yearly proportion of unplanned transfers to ICU from MET and non-MET wards.

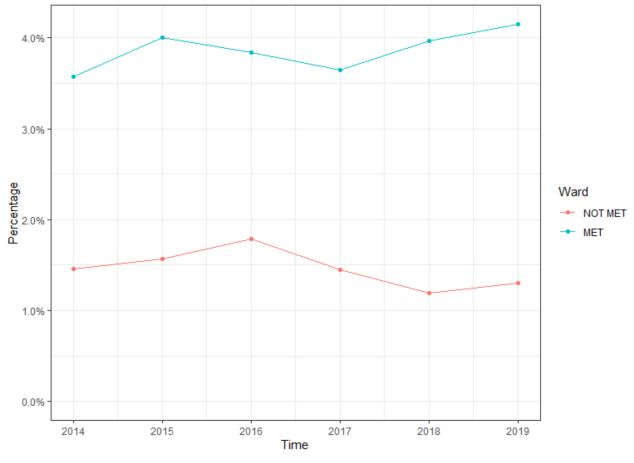

Figure 2. Yearly in-hospital mortality in the MET and non-MET wards.

characteristics, the effectiveness observed in one hospital does not guarantee successful implementation in different contexts. Furthermore, because the risk of deterioration is not the same for all hospitalized patients and depends on their clinical conditions, the effectiveness of RRS implementation is likely not homogeneous across hospital wards. For example, respiratory distress is one of the most common causes of RRS intervention[21] and this complication is more frequent in medical or pulmonology wards. Thus, the effectiveness of RRS implementation may not be directly translatable across different wards. Secondly, we cannot rule out the possibility that changes in the epidemiology of hospital admissions may have influenced both ICU transfers and mortality rates. For example, a decreased severity of the hospitalized patients over the years of the study may explain the decreasing trend of unplanned ICU transfers. However, this seems unlikely, given the consistency of the number of admissions and of the distribution of patients across MET and non-MET wards over time. Moreover, the difference-in-differences design is designed to account for temporal changes in both MET and non-MET wards and, therefore, the results of the main analysis are robust to such temporal variations. We also acknowledge limitations in the implemented RRS. The NEWS score was not applied to all admissions throughout the entire duration of hospitalization but only to overnight admissions of selected categories of patients. Furthermore, an updated version of the early warning score adopted in the RRS (*i.e.*, the NEWS2) was released after the RRS was implemented.

Conclusions

The study documented the safety of the RRS implemented in the Maggiore Hospital in Lodi and the non-inferiority of the ED-managed MET compared to the traditional interdivisional guard in terms of unplanned ICU transfers and mortality rates.

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