Published in final edited form as:

Resuscitation. 2018 July ; 128: 191–197. doi:10.1016/j.resuscitation.2018.05.013.

Rapid Response Systems

Patrick G Lyons, MD¹, Dana P Edelson, MD², and Matthew M Churpek, MD, MPH, PhD^{2,*}

¹Washington University in St. Louis, Department of Medicine, Division of Pulmonary and Critical Care Medicine

²Department of Medicine, University of Chicago, Chicago, IL

Abstract

Introduction—Rapid response systems are commonly employed by hospitals to identify and respond to deteriorating patients outside of the intensive care unit. Controversy exists about the benefits of rapid response systems.

Aims—We aimed to review the current state of the rapid response literature, including evolving aspects of afferent (risk detection) and efferent (intervention) arms, outcome measurement, process improvement, and implementation.

Data sources—Articles written in English and published in PubMed.

Results—Rapid response systems are heterogeneous, with important differences among afferent and efferent arms. Clinically meaningful outcomes may include unexpected mortality, in-hospital cardiac arrest, length of stay, cost, and processes of care at end of life. Both positive and negative interventional studies have been published, although the two largest randomized trials involving rapid response systems - the Medical Early Response and Intervention Trial (MERIT) and the Effect of a Pediatric Early Warning System on All-Cause Mortality in Hospitalized Pediatric Patients (EPOCH) trial - did not find a mortality benefit with these systems, albeit with important limitations. Advances in monitoring technologies, risk assessment strategies, and behavioral ergonomics may offer opportunities for improvement.

Conclusions—Rapid responses may improve some meaningful outcomes, although these findings remain controversial. These systems may also improve care for patients at the end of life.

*Corresponding author and requests for reprints: Matthew M Churpek, Mail: University of Chicago Medical Center, Section of Pulmonary and Critical Care Medicine, 5841 South Maryland Avenue, MC 6076, Chicago, IL 60637, matthew.churpek@uchospitals.edu; Office: (773) 702-1092; Fax: (773) 702-6500.

Conflicts of Interest and Source of Funding: Dr. Lyons is supported by a T32 grant (5T32 HL007317). Dr. Churpek is supported by a career development award from the NHLBI (K08 HL121080), an R01 from NIGMS (R01 GM123193), and has received honoraria from Chest for invited speaking engagements. Drs. Churpek and Edelson have a patent pending (ARCD. P0535US.P2) for risk stratification algorithms for hospitalized patients. In addition, Dr. Edelson has received research support from Philips Healthcare (Andover, MA), research support from the American Heart Association (Dallas, TX) and Laerdal Medical (Stavanger, Norway), and research support from EarlySense (Tel Aviv, Israel). She has ownership interest in Quant HC (Chicago, IL), which is developing products for risk stratification of hospitalized patients.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Rapid response systems are expected to continue evolving with novel developments in monitoring technologies, risk prediction informatics, and work in human factors.

Keywords

Rapid response systems; medical emergency teams; rapid response teams

Introduction

First described in the 1990s as a strategy to bring additional resources to inpatients experiencing non-code medical emergencies,¹ rapid response systems (RRSs) have become commonplace in hospitals worldwide. Conceptually, RRSs are safety nets involving deterioration monitoring and alerts linked to an team of responders capable of providing critical care resources and interventions at the patient's current location, as well as the governance and self-assessment structures associated with these components. Many observational studies of RRSs have shown benefit in terms of decreased hospital cardiac arrest and mortality rates, but the only multicenter randomized study, the 2005 Medical Early Response Intervention and Therapy (MERIT) trial, did not demonstrate these benefits,² which has contributed to controversy about the value of the RRS. This review aims to describe the current state of the RRS literature.

Rationale and Development of Rapid Response Systems

A nontrivial number of hospitalized patients - ranging from 3% to 9% - experience clinical deterioration, defined as movement "from one clinical state to a worse clinical state which increases their individual risk of morbidity... or death."³ Among patients outside the intensive care unit (ICU), clinical deterioration produces a mismatch between an acute increase in a patient's needs and available resources.⁴ Deterioration events, such as cardiac arrests, are frequently preceded by abnormal vital signs hours before they occur.⁵ Recognized and acted on appropriately, such antecedents might represent windows of opportunity in which to rescue deteriorating patients before irreversible morbidity or mortality occurs.

This concept of "rescue" for the hospitalized patient has led to the development of rapid response systems (RRS) designed to identify and respond to deteriorating patients by moving critical personnel, diagnostics, and interventions to the bedside. In 2004, the Institute for Healthcare Improvement (IHI) began its "100,000 Lives Campaign," which called for all United States hospitals to deploy rapid response teams.⁶ Subsequently, the Joint Commission mandated that United States hospitals should establish RRSs as part of the 2008 National Patient Safety Goals.⁷ Most recently, the 2015 American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care continue to recommend RRSs, especially in general care wards.⁸

Current Guidelines and Standards of Practice

Although the terms RRS, rapid response team (RRT), and medical emergency team (MET) are sometimes used interchangeably, formal definitions for each term exist. RRSs refer to an

organization's "safety net" for deteriorating inpatients, with components commonly categorized into 1) afferent activities (detection of deterioration and triggering a response), 2) efferent response, 3) self-evaluation and quality improvement, and 4) administration and governance (Figure 1).⁴ Within the efferent limb of the RRS, an RRT is typically a nurse-led team of responders while a MET is led by a physician, often an intensivist, who can prescribe critical care interventions, obtain central access, and facilitate airway management.⁹ On recent estimate, most United States hospitals employ some sort of RRS,¹⁰ and numbers are increasing throughout other parts of the world. The standard method for reporting activation rates is calls per 1,000 patient admissions;⁴ utilization rates among mature systems vary but are ideally close to 40 per 1,000 admissions given prior studies showing associations between RRS "dose" and outcomes.⁹

Team Composition

Team Members

The optimal composition of rapid response teams is unknown but probably varies based on institutional resources, preferences, and goals.¹¹ Potential members of RRSs include physicians, nurses, respiratory therapists, and pharmacists.^{12,13}

Team Leaders

As noted above, a MET is typically physician-led, while nurses generally lead RRTs. Presence of a physician may not affect mortality, although these assessments may be biased.¹³ Among MET leaders, level of training may not influence mortality.¹⁴ While the physician leader for a MET is often an intensivist,¹⁵ the patient's primary team of caregivers serves as the rapid responders in some hospitals.¹⁶

Equipment

Responding teams should have access to real-time monitoring devices, tools for obtaining vascular access, and relevant interventions including medications and oxygen-delivery devices. Responders must also be able to review patient data quickly and efficiently. User-centered EHR interfaces or other health information technology might be used to avoid information overload or data corruption while presenting relevant data immediately.¹⁷

Setting

Most RRS activations occur on the inpatient wards, more frequently on medical wards than surgical wards,¹⁸ but may also be called to radiology or procedure areas and adjacent areas such as acute dialysis units.¹⁹ In tertiary hospitals, RRS activations commonly occur on subspecialty wards, which necessitates that the response team be equipped to deal with deterioration scenarios specific to these populations.²⁰ Over 10% of RRSs may be called for non-hospitalized patients, including outpatients, visitors, and hospital staff, often for similar reasons that inpatient RRS activations occur.²¹ These patients are typically referred to the emergency department for further triage and care.²¹ Use of the RRS in the ED is variable,²⁰ and unique patient and department needs may require a different model than the ward-based model

Activation of the RRS

Although some risk is random,³ other risk for hospitalized patients can be predicted by vital signs, and so more effective monitoring may improve outcomes,²² particularly since staff are frequently unaware of these abnormalities.²³ The afferent limb of an RRS involves several steps which must occur in series: monitoring for abnormal physiologic parameters, recognizing abnormality in a monitored value, and delivering a signal when a certain threshold of abnormality is met.¹⁶

Delays in RRS activation are common and influenced by sociocultural issues,²⁴ time of day, and patient-unit mismatch such as admission of medical patients to surgical wards.²⁵ Prolonged, these delays are associated with increased hospital mortality.²⁶ Mature RRSs are less likely to experience delayed activation,²⁶ and more likely to achieve appropriate “dosage,” commonly estimated as at least 25 calls per 1,000 admissions and ideally closer to 40.⁹ Mandatory activation when criteria are met, as opposed to voluntary activation, increases utilization and may improve outcomes.²⁷

Monitoring

Monitoring on the wards takes many forms, ranging from periodic assessment of vital signs to continuous electronic surveillance of heart rate, respiratory rate, pulse oximetry, and capnography. Notably, changes in hospital staffing overnight may result in decreased monitoring intensity or under-recognition of deterioration, which likely explains well-described diurnal variation in RRS activation rates.²⁵ This diurnal variation is associated with increased mortality at subsequent change of shift.²⁸

Activation Criteria

Staff concern is among the most common reasons for RRS activation,²⁹ and clinical judgment does appear to enhance prediction of deterioration.³⁰ Activation solely on subjective judgment often leads to RRS underutilization,⁴ and so most existing systems stipulate a set of objective activation criteria.

Many RRS utilize single- or multi-parameter vital sign abnormalities as triggers for RRS activation. These parameters often include hypotension, tachycardia or bradycardia, tachypnea, and depressed level of consciousness.²⁹ These criteria are limited in that they may be measured unreliably³¹ and are insensitive,³² but it is possible that automated measurement,³³ or quality improvement initiatives,³⁴ could improve reliability and predictive utility. On the other hand, automated measurement of respiratory rate appears less predictive of deterioration than manual measurement,³⁵ suggesting that manual measurements might be inflated or deflated based on the assessor’s clinical concern, thereby increasing their predictive value. Similarly, using cut-points (e.g. respiratory rate > 35) for single parameters may result in lost information and diminished predictive value, which may be why combinations of multiple subtle physiologic changes are often more predictive than a single large change.³⁶

Aggregate weighted multi-component early warning scores, such as the Modified Early Warning Score (MEWS) and the National Early Warning Score (NEWS), may be helpful in

identifying early deterioration by leveraging multiple abnormalities into a single score.^{36,37} These scores may be linked to protocols requiring more frequent vital sign assessments, or to rapid response activation. Automated activation of the intervention arm of the RRS may be associated with improved patient outcomes.³⁸ While these scores are more accurate than single-parameter systems, they remain limited in their generalizability and discriminatory performance.³⁷

As data science and informatics have advanced, more complex scores have been developed that utilize “big data” techniques and numerous variables from the electronic health record (EHR) to improve accuracy across ward settings.^{39,40} These tools generally produce a comprehensive “risk score” relating a patient’s probability of experiencing deterioration over a fixed future time period. The trigger threshold for RRS activation can be adjusted based on the hospital’s desired sensitivity, specificity, and number of alerts per day. Limitations of these tools include sparse data in low-monitored settings²² and the lack of specific responses to fit a score which describes risk but not any sort of recommendation.

Finally, some hospitals permit RRS activation by patients or family members. Although family-activated RRS have not been extensively studied, preliminary data suggest they are reliable indicators of deteriorating patients. In a pediatric hospital, more than half of family activations were in patients with abnormal vital signs which should have triggered RRS activation independently, and most required at least one intervention, with over 25% requiring ICU transfer.⁴¹

Proactive Rounding

Because acuity of illness exists along a spectrum, it is possible that graded responses to risk and deterioration can match patient needs to resources more appropriately than one -size-fits-all responses. It remains controversial whether RRSs should serve solely as reactive systems, or whether there is value to proactive rounding on stable patients at high risk for deterioration. These patients might be identified by a complex scoring system or another marker of risk, such as recent discharge from the ICU. Proactive rounding has been demonstrated to decrease ward cardiac arrests and deaths by increasing ICU transfers,⁴² but may also improve outcomes while permitting some patients to remain in their ward setting.⁴³

Interventions Delivered

Medical Interventions

Most RRS activations result in one or more interventions for the patient, ranging from additional diagnostic testing,⁴⁴ obtaining intravenous or central access, or delivering respiratory, hemodynamic, or neurologic support.^{44,45} Rapid responders frequently administer empiric antibiotics for sepsis, and use of hospital-based algorithms may ensure more frequent use of appropriate empiric choices.⁴⁶

Cognitive Framework and Triage

Beyond testing and discrete medical interventions, rapid responders provide a critical care-based cognitive framework and may be able to break from the concept of “clinical futile cycles” through different approaches to problems.⁴⁷ Standardized approaches to certain phenotypes of hospital emergencies may ensure consistent application of best practices for urgent diagnostics and interventions.⁴⁸ Rapid responders also need triage ability; in general, RRS leaders should have the authority to transfer patients to higher levels of care, or at least have close contact with destinations such as the ICU.⁴

Goals of Care

In the 2012 National Confidential Enquiry into Patient Outcome and Death report, 62% of inpatients experiencing cardiac arrest showed physiologic instability for 6 or more hours prior to the arrest; despite this finding, only 22% had explicitly recorded documentation of decisions related to resuscitation.⁴⁹ Rapid responders frequently encounter patients in these pre-arrest windows of instability^{50–52} and must make determinations as to whether the patient’s clinical deterioration is due to a reversible insult or progression of a terminal process. This determination is often challenging, and relatively few tools are available to assist rapid responders who may not have encountered the patient previously. Recently, machine learning has used EHR data to identify patients at high risk of death after rapid response,⁵³ which may help facilitate care decisions and goal discussions. One study using EWS criteria to prompt palliative care discussions led to improved documentation of patient preferences, but not code status changes or palliative care consultations.⁵⁴ It remains controversial whether the RRT should address goals of care and to discuss and deliver palliative interventions directly or should engage the primary care team when able.²⁰

Finally, RRS activations commonly occur for patients with existing DNR orders,⁴⁵ and must identify and deliver interventions which fit within the patient’s stated goals of care. In all of these situations, optimal RRS performance should include clear communication with patients, family, nurses, and other providers to formulate a plan based on patient preferences with attention to alleviation of symptoms, family needs, and staff needs.⁵⁵ Formal recommendations exist to improve integration between palliative care and RRSs, including training and competency measurement, institutional attention to advanced care planning, and pastoral care support for the RRS.⁵⁵

Outcomes

Patients for whom the RRS is activated experience high rates of ICU admission and mortality.⁵² Much of the controversy surrounding rapid response systems involves conflicting data about the benefits these systems provide, which outcomes are meaningful, and how to measure them.

Inpatient Mortality

Hospital mortality among patients receiving a rapid response is high but variable, with a median mortality near 25%.²⁸ A number of observational trials have reported decreases in mortality with RRS implementation,^{13,56–58} but these findings have not been universal,⁴⁴

and the observational pre/post nature of these studies leaves open the possibility of residual confounding and Hawthorne effect.⁴⁷ In an early landmark study in 2004, Priestley et al. reported a ward-randomized trial showing that an RRS reduced hospital mortality.⁵⁹ However, in 2005, the Medical Early Response Intervention and Therapy (MERIT) trial, a multicenter, cluster-randomized controlled trial of METs, failed to demonstrate a benefit in terms of its composite endpoint of death, unexpected cardiac arrest, and unplanned ICU admission.² In this trial, control hospitals utilized existing cardiac arrest response teams, but almost half of these activations occurred without an arrest, essentially functioning as an RRS and narrowing the gap between control and intervention arms. Coupled with lower than expected mortality and very low activation rates in the intervention arm, these findings suggest that MERIT was underpowered for the outcome of interest. Finally, a recent multinational randomized trial found that use of a pediatric EWS did not reduce hospital mortality;⁶⁰ in this trial, control hospitals practicing “usual care” had similar numbers of rapid response teams than intervention hospitals, and more control hospitals were university-affiliated and provided specialty services such as organ transplant and extra-corporeal life support.

Unexpected Inpatient Mortality

It has been suggested that because some hospital deaths are not predictable or preventable, a more appropriate outcome might be unexpected mortality, defined as death after attempted resuscitation. Several observational studies have found improved unexpected mortality with stable total mortality, even adjusted for secular trends.^{16,56} Post-hoc analysis of the MERIT trial suggests that each 10% increase in MET calls led to a reduction of 2 unexpected cardiac arrests/10,000 admissions, 2.2 overall cardiac arrests/10,000 admissions, and 0.94 unexpected deaths/10,000 admissions.⁶¹

As mentioned above, inconsistent findings of benefit may also relate to “under-dosing” or inconsistent activation of the RRS, in that higher utilization has been associated with improved patient outcomes.^{9,47}

Longer-Term Mortality

Beyond hospital mortality, long term outcomes of patients receiving rapid response interventions are not well known and this is an important area of future study.⁶²

In-Hospital Cardiac Arrest

Most evaluations of RRS outcomes have shown that RRS activations are associated with fewer cardiac arrests on the wards or fewer overall in-hospital cardiac arrests.^{13,44,47,58,63} One concern with measuring only the ward arrest rate is that it may not reflect patients who transfer to the ICU only to experience cardiac arrest once there. This concern has been reflected in one meta-analysis, which identified a reduction in cardiac arrest outside the ICU without any change in inpatient mortality.⁶⁴ Moreover, this meta-analysis showed that in studies which did report mortality benefits to the RRS, these benefits exceeded the number of cardiac arrests averted, which suggests confounding.⁶⁴ Additionally, even with a mature RRS, predictable and potentially preventable arrests still occurred, which may be related to monitoring differences or delays activating the RRS.⁶⁵

Length of Stay

Rapid response systems have a varied effect on hospital and ICU length of stay.^{16,44,58,59} It is possible that a rapid response resulting in transfer to the ICU could produce lead-time effects on ICU length of stay, or that it could increase length of stay which would otherwise be short in a patient who died.

End of Life Care

RRS activations increase the number of patients designated do-not-resuscitate (DNR) status⁶⁶ and appear to lead to family meetings and code status changes, even when not called explicitly for these purposes.⁶⁷ RRS implementation has been associated with improved documentation of patient pain and distress, chaplain encounters, and documentation of comfort care orders,⁶⁸ although not all systems have shown these results⁵¹

Hospital Logistics

Decreased ward nurse staffing is associated with risk for clinical deterioration and other adverse outcomes,^{69,70} and critical illness in one ward patient increases risk of neighboring patients experiencing deterioration.⁷¹ It is unknown whether rapid response utilization facilitates re-allocation of ward resources in order to mitigate this effect.

Patient Satisfaction

Rapid response systems have been hypothesized to increase patient and family satisfaction, either by fulfilling the “rescue” mandate, delivering appropriate end of life care around the clock,⁵⁰ or by using early warning systems to minimize disruptions to lower-risk patients.⁷² Few studies have evaluated these outcomes directly,⁴¹ although several studies have reported staff perceptions that patients and families are highly satisfied,⁷³ and that high-utilization organizations are perceived as having more satisfactory rapid response systems than low-utilization hospitals.¹¹

Team Satisfaction

Similarly, effective RRSs are hypothesized to improve staff satisfaction, both for RRS members and those on the wards they serve, by improving the ratio of patient needs to resources.⁷⁰ Despite recommendations that RRS satisfaction be routinely measured,⁴ it appears that this outcome is infrequently reported.⁵⁰

Cost

Rapid response systems require staffing with appropriately trained providers, equipment, and investments in data acquisition and review, along with potentially investing in monitoring technology. It is expected that these requirements make the RRS costly. By contrast, there may be financial benefit to concentrating emergency response expertise among a relatively small number of personnel, which could be cheaper than training all hospital employees to respond to emergencies.⁷⁴ Further cost savings might be realized as the RRS shifts the allocation of ward resources, allowing nurses with deteriorating patients to attend to their other duties, or by decreasing costly monitoring of lower-risk patients as identified by an EWS.⁷² Finally, as bundled payments become more common for

hospitalization, the RRS could result in decreasing costs related to prolonged ICU stays or hospitalizations. None of these hypotheses have been formally evaluated, and the cost-effectiveness of RRSs has not been studied in robust fashion.

Self-Measurement and Process Improvement—Optimal RRSs have been described as self-evaluative and focused on using feedback to improve processes of care.⁴ As a target outcome, the Agency for Healthcare Research and Quality (AHRQ) has listed failure to rescue as a formal patient safety indicator for reporting and tracking alongside risk-adjusted mortality.⁷⁵ It is acknowledged that systematic differences between hospitals contributes to significant variability in failure to rescue rates,^{69,75} and it is likely that hospitals vary in the types and amount of additional data collected about their RRS,²⁰ although guidelines for monitoring and reporting outcomes exist.⁷⁶ Quality improvement initiatives associated with RRSs permit surveillance for medical errors and have permitted numerous explorations of care process improvement,^{30,77,78} as well as educational opportunities for nursing and medical staff.^{79,80} Finally, simulation may be an effective tool for training RRS teams.⁷⁷

Barriers to Implementation and Implementation Strategies

Barriers to RRS implementation are likely to vary across institutions, and systematic assessment may be helpful in identifying and overcoming these obstacles,⁸¹ both to implement the system and to ensure it is sustainable within an organization.⁸² Commonly cited obstacles to RRS implementation or sustainability include lack of awareness of the system, activation criteria, or response protocols,^{83–85} organizational culture and resistance to stepping outside norms or silos,^{4,82,83} and resource scarcity.^{82,86} Intimidation or fear of appearing inadequate has been cited as a potential reason for nursing underutilization of RRSs,^{83,86} but this may vary among institutions.⁸⁴

Multiple studies have identified strategies and tools useful during RRS implementation, including initial and ongoing training and feedback efforts, administrative support paired with active champions among relevant stakeholders, resources and equipment, and efforts to ensure a supportive and communicative culture.^{10,47,82,85}

Questions and Controversies

The major controversy surrounding rapid response systems is whether their use truly improves meaningful outcomes for patients. To date, the largest and most methodologically robust evaluation of the RRS did not identify a major benefit, albeit with the limitations outlined above. Reductions in cardiac arrest rates have been noted in most evaluations, but these findings may also be limited, either by confounding,⁶⁴ or by shifting risk without truly providing “rescue” – ward arrests might be avoided by moving patients to the ICU to arrest, or that unexpected arrests are averted by changing code status. Given the significant cost these resource-intensive systems incur, these limited benefits might not be enough. The extent to which RRS utilization, or “dosing,” influences this relationship has not been evaluated in an interventional trial;^{9,47} no study has evaluated a mature RRS against an uncontaminated control group, and doing so in the future may be logistically challenging and prohibitively costly.

Moreover, concerns exist that in some situations, the RRS serves only as a bandage for incorrect triage.⁸⁷ To that end, 11% of RRT calls in an inpatient dialysis unit occurred on arrival vital sign checks, before dialysis had begun,¹⁹ suggesting the patients may have been displaying signs of deterioration before departing the wards. Similarly, emergency department vital signs predict RRS activations during the first 12 hours of admission, and these patients have more frequent ICU admissions and worse mortality.⁸⁸ More rigorous study of the benefits of RRSs, including cost-effectiveness, are needed, although the logistics of performing such a study are challenging.

Future Directions

Technology

The afferent limb of RRSs may continue to improve with technological advancements (Table 1), including improvements to early warning systems via additional patient data for validation studies,⁸⁹ inclusion of new information sources^{22,90} including systematic subjective assessments,³⁰ and use of novel informatics approaches such as deep learning⁹¹ and natural language processing. As wearable devices advance and become more widely used, new data streams may become available for inclusion into these assessments, which could further improve accuracy. Necessary alongside these developments are efforts to minimize false positive alarm activation to avoid alarm fatigue.⁹²

New technologies may be able to augment training experiences for rapid responders, as well. Recently, augmented reality glasses were shown to improve some aspects of performance during pediatric and adult code simulations.⁹³ These tools have not yet been evaluated for rapid response scenarios, nor have they been evaluated outside of simulated environments.

Beyond track and trigger systems and improved training, emerging technologies may help rapid responders improve the appropriateness, reliability, and speed of interventions. For example, one group recently used routinely collected data from one hospital's MET experiences to develop pre-emptive management algorithms for common deterioration triggers.⁹⁴ Further work in this area could allow some patients to receive initial interventions while rapid responders are en route to the bedside, or even with remote leadership via telemedicine.⁹⁵

Human Factors

One final area for future work involves human factors, organizational psychology, and ergonomics. Communication between rapid responders and other hospital staff are frequently cited as barriers to more frequent utilization,²⁴ and may also limit performance during medical emergencies.⁹⁶ Simulation is well studied for CPR, but needs further evaluation for RRSs. Newer areas meriting additional study include training on stress-coping techniques,⁹⁷ application of lean strategies to the RRS,²⁰ and increased emphasis on interprofessional training.⁹⁸

Conclusions

Rooted in continuous self-assessment, the RRS is not a static entity. Since their initial development over twenty years ago, these systems have evolved new monitoring technologies, risk assessments, and response models. Rapid responses may decrease in-hospital cardiac arrests and hospital mortality, although these findings remain controversial. The RRS may also be a useful tool to improve care for patients at the end of life. As monitoring and informatics technology progresses and work in human factors and ergonomics advances, the RRS will continue to evolve.

References

1. Daffurn K, Lee A, Hillman KM, Bishop GF, Bauman A. Do nurses know when to summon emergency assistance? *Intensive Crit Care Nurs*. 1994; 10(2):115–120. [PubMed: 8012150]
2. Hillman K, Chen J, Cretikos M, et al. Introduction of the medical emergency team (MET) system: A cluster-randomised controlled trial. *Lancet*. 2005; 365(9477):2091–2097. [PubMed: 15964445]
3. Jones D, Mitchell I, Hillman K, Story D. Defining clinical deterioration. *Resuscitation*. 2013; 84(8): 1029–1034. [PubMed: 23376502]
4. DeVita MA, Bellomo R, Hillman K, et al. Findings of the First Consensus Conference on Medical Emergency Teams. *Crit Care Med*. 2006; 34(9):2463–2478. [PubMed: 16878033]
5. Andersen LW, Kim WY, Chase M, et al. The prevalence and significance of abnormal vital signs prior to in-hospital cardiac arrest. *Resuscitation*. 2016; 98:112–117. [PubMed: 26362486]
6. Berwick DM, Calkins DR, McCannon CJ, Hackbarth AD. The 100,000 Lives Campaign. *JAMA*. 2006; 295(3):324. [PubMed: 16418469]
7. The Joint Commission. [Accessed February 15, 2018] National patient safety goals. 2008. http://www.jointcommission.org/PatientSafety/NationalPatientSafetyGoals/08_hap_npsgs.htm
8. Kronick SL, Kurz MC, Lin S, et al. Part 4: Systems of care and continuous quality improvement: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2015; 132(18):S397–S413. [PubMed: 26472992]
9. Jones D, Bellomo R, DeVita MA. Effectiveness of the Medical Emergency Team: The importance of dose. *Crit Care*. 2009; 13(5):1–5.
10. Edelson DP, Yuen TC, Mancini ME, et al. Hospital cardiac arrest resuscitation practice in the United States: A nationally representative survey. *J Hosp Med*. 2014; 9(6):353–357. [PubMed: 24550202]
11. Stollendorf DP, Jones CB. Deployment of rapid response teams by 31 hospitals in a statewide collaborative. *Jt Comm J Qual Patient Saf*. 2015; 41(4):186–192. [PubMed: 25977203]
12. Groth CM, Acquisto NM. Pharmacists as members of the rapid response team. *J Pharm Pract*. 2016; 29(2):116–120. [PubMed: 25107424]
13. Maharaj R, Raffaele I, Wendon J. Rapid response systems: A systematic review and meta-analysis. *Crit Care*. 2015; 19(1):1–15. [PubMed: 25560635]
14. Morris DS, Schweickert W, Holena D, et al. Differences in outcomes between ICU attending and senior resident physician led medical emergency team responses. *Resuscitation*. 2012; 83(12): 1434–1437. [PubMed: 22841611]
15. Jones D, Drennan K, Hart GK, Bellomo R, Steven AR. Rapid Response Team composition, resourcing and calling criteria in Australia. *Resuscitation*. 2012; 83(5):563–567. [PubMed: 22067975]
16. Howell MD, Ngo L, Folcarelli P, et al. Sustained effectiveness of a primary-team-based rapid response system. *Crit Care Med*. 2012; 40(9):2562–2568. [PubMed: 22732285]
17. Fletcher GS, Aaronson BA, White AA, Julka R. Effect of a real-time electronic dashboard on a rapid response system. *J Med Syst*. 2017; 42(1):5. [PubMed: 29159719]

18. Silva R, Saraiva M, Cardoso T, Aragão IC. Medical Emergency Team: How do we play when we stay? Characterization of MET actions at the scene. *Scand J Trauma Resusc Emerg Med.* 2016; 24(1):33. [PubMed: 27000277]
19. Galhotra S, DeVita MA, Dew MA, Simmons RL. A 5-year analysis of rapid response system activation at an in-hospital haemodialysis unit. *Qual Saf Heal Care.* 2010; 19(6):2–6.
20. Rojas JC, Shappell C, Huber M. Advances in rapid response, patient monitoring, and recognition of and response to clinical deterioration. *Jt Comm J Qual Patient Saf.* 2017; 43(12):686–694. [PubMed: 29173290]
21. Dechert TA, Sarani B, McMaster M, et al. Medical emergency team response for the non-hospitalized patient. *Resuscitation.* 2013; 84(3):276–279. [PubMed: 22776516]
22. DeVita MA, Smith GB, Adam SK, et al. “Identifying the hospitalised patient in crisis”- A consensus conference on the afferent limb of Rapid Response Systems. *Resuscitation.* 2010; 81(4): 375–382. [PubMed: 20149516]
23. Fuhrmann L, Lippert A, Perner A, Østergaard D. Incidence, staff awareness and mortality of patients at risk on general wards. *Resuscitation.* 2008; 77(3):325–330. [PubMed: 18342422]
24. Shearer B, Marshall S, Buist MD, et al. What stops hospital clinical staff from following protocols? An analysis of the incidence and factors behind the failure of bedside clinical staff to activate the rapid response system in a multi-campus Australian metropolitan healthcare service. *BMJ Qual Saf.* 2012; 21(7):569–575.
25. Schmid-Mazzocchi A, Hoffman LA, Wolf GA, Happ MB, Devita MA. The use of medical emergency teams in medical and surgical patients: Impact of patient, nurse and organisational characteristics. *Qual Saf Heal Care.* 2008; 17(5):377–381.
26. Calzavacca P, Licari E, Tee A, et al. The impact of Rapid Response System on delayed emergency team activation patient characteristics and outcomes - A follow-up study. *Resuscitation.* 2010; 81(1):31–35. [PubMed: 19854557]
27. Jones CM, Bleyer AJ, Petree B. Evolution of a rapid response system from voluntary to mandatory activation. *Jt Comm J Qual Patient Saf.* 2010; 36(6):266–270. [PubMed: 20564888]
28. Churpek MM, Edelson DP, Lee JY, Carey K, Snyder A. Association between survival and time of day for rapid response team calls in a national registry. *Crit Care Med.* 2017; 45(10):1677–1682. [PubMed: 28742548]
29. Chen J, Bellomo R, Hillman K, Flabouris A, Finfer S. Triggers for emergency team activation: A multicenter assessment. *J Crit Care.* 2010; 25(2):359.e1–359.e7.
30. Patel AR, Zdravetz FJ, Young RS, Williams MV, Churpek MM, Edelson DP. Letter: The value of clinical judgment in the detection of clinical deterioration. *JAMA Intern Med.* 2015; 175(3):456–458. [PubMed: 25558851]
31. Badawy J, Nguyen OK, Clark C, Halm EA, Makam AN. Is everyone really breathing 20 times a minute? Assessing epidemiology and variation in recorded respiratory rate in hospitalised adults. *BMJ Qual Saf.* 2017; 26(10):832–836.
32. Smith GB, Prytherch DR, Schmidt PE, Featherstone PI, Higgins B. A review, and performance evaluation, of single-parameter “track and trigger” systems. *Resuscitation.* 2008; 79(1):11–21. [PubMed: 18620794]
33. Bellomo R, Ackerman M, Bailey M, et al. A controlled trial of electronic automated advisory vital signs monitoring in general hospital wards. *Crit Care Med.* 2012; 40(8):2349–2361. [PubMed: 22809908]
34. Keshvani N, Berger K, Nguyen OK, Makam AN. Roadmap for improving the accuracy of respiratory rate measurements. *BMJ Qual Saf.* 2017 Nov. bmjqs-2017-007516. Epub ahead of print.
35. Churpek MM, Snyder A, Twu NM, Edelson DP. Accuracy comparisons between manual and automated respiratory rate for detecting clinical deterioration in ward patients. *J Hosp Med.* Feb. 2018 Epub ahead of print.
36. Jarvis S, Kovacs C, Briggs J, et al. Aggregate National Early Warning Score (NEWS) values are more important than high scores for a single vital signs parameter for discriminating the risk of adverse outcomes. *Resuscitation.* 2015; 87:75–80. [PubMed: 25433295]

37. Smith GB, Prytherch DR, Schmidt PE, Featherstone PI. Review and performance evaluation of aggregate weighted “track and trigger” systems. *Resuscitation*. 2008; 77(2):170–179. [PubMed: 18249483]
38. Subbe CP, Duller B, Bellomo R. Effect of an automated notification system for deteriorating ward patients on clinical outcomes. *Crit Care*. 2017; 21(1):1–9. [PubMed: 28057037]
39. Kipnis P, Turk BJ, Wulf DA, et al. Development and validation of an electronic medical record-based alert score for detection of inpatient deterioration outside the ICU. *J Biomed Inform*. 2016; 64:10–19. [PubMed: 27658885]
40. Churpek MM, Yuen TC, Winslow C, et al. Multicenter development and validation of a risk stratification tool for ward patients. *Am J Respir Crit Care Med*. 2014; 190(6):649–655. [PubMed: 25089847]
41. Bavare AC, Thomas JK, Elliott EP, Morgan AC, Graf JM. Family-initiated pediatric rapid response: Characteristics, impetus, and outcomes. *J Healthc Qual*. 2017; 0(0):1.
42. Guirgis FW, Gerdik C, Wears RL, et al. Proactive rounding by the rapid response team reduces inpatient cardiac arrests. *Resuscitation*. 2013; 84(12):1668–1673. [PubMed: 23994805]
43. Hueckel RM, Turi JL, Cheifetz IM, Mericle J, Meliones JN, Mistry KP. Beyond rapid response teams: Instituting a “Rover Team” improves the management of at-risk patients, facilitates proactive interventions, and improves outcomes. *Adv Patient Saf New Dir Altern Approaches (Vol 3 Perform Tools)*. 2008:1–12.
44. Chan PS, Khalid A, Longmore LS, Berg RA, Kosiborod M, Spertus JA. Implementation of a Rapid Response Team Hospital-wide Code Rates and Mortality Before and After Hospital-wide Code Rates and Mortality Before and After Implementation of a Rapid Response Team. *JAMA*. 2008; 300(21):7–11.
45. Coventry C, Flabouris A, Sundararajan K, Cramey T. Rapid response team calls to patients with a pre-existing not for resuscitation order. *Resuscitation*. 2013; 84(8):1035–1039. [PubMed: 23376582]
46. Miano TA, Powell E, Schweickert WD, Morgan S, Binkley S, Sarani B. Effect of an antibiotic algorithm on the adequacy of empiric antibiotic therapy given by a medical emergency team. *J Crit Care*. 2012; 27(1):45–50. [PubMed: 21798704]
47. Buist M, Harrison J, Abaloz E, Van Dyke S. Quality improvement report: Six year audit of cardiac arrests and medical emergency team calls in an Australian outer metropolitan teaching hospital. *Br Med J*. 2007; 335(7631):1210–1212. [PubMed: 18048504]
48. Subbe CP, Kellett J, Barach P, et al. Crisis checklists for in-hospital emergencies: expert consensus, simulation testing and recommendations for a template determined by a multi-institutional and multi-disciplinary learning collaborative. *BMC Health Serv Res*. 2017; 17(1):1–8. [PubMed: 28049468]
49. Perkins GD, Temple RM, George R. Time to intervene: Lessons from the NCEPOD report. *Resuscitation*. 2012; 83(11):1305–1306. [PubMed: 22955050]
50. Jones D, Moran J, Winters B, Welch J. The rapid response system and end-of-life care. *Curr Opin Crit Care*. 2013; 19(6):616–623. [PubMed: 23799463]
51. Downar J, Barua R, Rodin D, et al. Changes in end of life care 5 years after the introduction of a rapid response team: A multicentre retrospective study. *Resuscitation*. 2013; 84(10):1339–1344. [PubMed: 23499898]
52. Bannard-Smith J, Lighthall GK, Subbe CP, et al. Clinical outcomes of patients seen by Rapid Response Teams: A template for benchmarking international teams. *Resuscitation*. 2016; 107:7–12. [PubMed: 27417561]
53. Shappell C, Snyder A, Edelson DP, Churpek MM. Predictors of in-hospital mortality after rapid response team calls in a 274 hospital nationwide sample. *Crit Care Med*. 2018:1. Epub ahead of print. [PubMed: 28863012]
54. Picker D, Dans M, Heard K, et al. A randomized trial of palliative care discussions linked to an automated early warning system alert. *Crit Care Med*. 2017; 45(2):234–240. [PubMed: 27768613]
55. Nelson JE, Mathews KS, Weissman DE, et al. Integration of palliative care in the context of rapid response: A report from the improving palliative care in the ICU advisory board. *Chest*. 2015; 147(2):560–569. [PubMed: 25644909]

56. Jung B, Daurat A, de Jong A, et al. Rapid response team and hospital mortality in hospitalized patients. *Intensive Care Med.* 2016; 42(4):1–11. [PubMed: 26493386]
57. Evans RS, Kuttler KG, Simpson KJ, et al. Automated detection of physiologic deterioration in hospitalized patients. *J Am Med Informatics Assoc.* 2015; 22(2):350–360.
58. Kollef MH, Heard K, Chen Y, Lu C, Martin N, Bailey T. Mortality and length of stay trends following implementation of a rapid response system and real-time automated clinical deterioration alerts. *Am J Med Qual.* 2017; 32(1):12–18. [PubMed: 26566998]
59. Priestley G, Watson W, Rashidian A, et al. Introducing Critical Care Outreach: a ward-randomised trial of phased introduction in a general hospital. *Intensive Care Med.* 2004; 30(7):1398–1404. [PubMed: 15112033]
60. Parshuram CS, Dryden-Palmer K, Farrell C, et al. Effect of a pediatric early warning system on all-cause mortality in hospitalized pediatric patients. *JAMA.* 2018:1–11.
61. Chen J, Bellomo R, Flabouris A, Hillman K, Finfer S. The relationship between early emergency team calls and serious adverse events. *Crit Care Med.* 2009; 37(1):148–153. [PubMed: 19050625]
62. Tirkkonen J, Tamminen T, Skrifvars MB. Outcome of adult patients attended by rapid response teams: A systematic review of the literature. *Resuscitation.* 2017; 112:43–52. [PubMed: 28087288]
63. Buist MD, Moore GE, Bernard SA, et al. Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: A preliminary study. *BMJ.* 2002; 324(7334):387–390. [PubMed: 11850367]
64. Chan PS, Jain R, Nallmothu BK, Berg RA, Sasson C. Rapid response teams: A systematic review and meta-analysis. *Arch Intern Med.* 2010; 170(1):18–26. [PubMed: 20065195]
65. Galhotra S, DeVita MA, Simmons RL, Dew MA. Mature rapid response system and potentially avoidable cardiopulmonary arrests in hospital. *Qual Saf Heal Care.* 2007; 16(4):260–265.
66. Chen J, Flabouris A, Bellomo R, Hillman K, Finfer S. The Medical Emergency Team system and not-for-resuscitation orders: Results from the MERIT study. *Resuscitation.* 2008; 79(3):391–397. [PubMed: 18952354]
67. Smith RL, Hayashi VN, Lee YI, Navarro-Mariazeta L, Felner K. The medical emergency team call: A sentinel event that triggers goals of care discussion. *Crit Care Med.* 2014; 42(2):322–327. [PubMed: 23989179]
68. Vazquez R, Gheorghe C, Grigoriyan A, Palvinskaya T, Amoteng-Adjepong Y, Manthous CA. Enhanced end-of-life care associated with deploying a rapid response team: a pilot study. *J Hosp Med.* 2009; 4(7):449–452. [PubMed: 19753581]
69. Needleman J, Buerhaus P, Mattke S, Stewart M, Zelevinsky K. Nurse-staffing levels and the quality of care in hospitals. *N Engl J Med.* 2002; 346(22):1715–1722. [PubMed: 12037152]
70. Aiken LH. Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *JAMA.* 2002; 288(16):1987. [PubMed: 12387650]
71. Volchenboum SL, Mayampurath A, Göksu-Gürsoy G, Edelson DP, Howell MD, Churpek MM. Association between in-hospital critical illness events and outcomes in patients on the same ward. *JAMA.* 2016; 316(24):2674. [PubMed: 28027358]
72. Yoder JC, Yuen TC, Churpek MM, Arora VM, Edelson DP. A prospective study of nighttime vital sign monitoring frequency and risk of clinical deterioration. *JAMA Intern Med.* 2013; 173(16):1554–1555. [PubMed: 23817602]
73. Kukreti V, Gaiteiro R, Mohseni-Bod H. Implementation of a pediatric rapid response team: Experience of the Hospital for Sick Children in Toronto. *Indian Pediatr.* 2014; 51(1):11–15. [PubMed: 24561462]
74. DeVita MA, Hillman K. Potential sociological and political barriers to Medical Emergency Team implementation. *Med Emerg Teams.* 1994:91–103.
75. Agency for Healthcare Research and Quality. Guide to Patient Safety Indicators. Version 3.1. Health Care (Don Mills). 2007:76.
76. Peberdy MA, Cretikos M, Abella BS, et al. Recommended guidelines for monitoring, reporting, and conducting research on medical emergency team, outreach, and rapid response systems: An Utstein-style scientific statement. *Circulation.* 2007; 116(21):2481–2500. [PubMed: 17993478]

77. Braithwaite RS, DeVita MA, Mahidhara R, Simmons RL, Stuart S, Foroida M. Use of medical emergency team (MET) responses to detect medical errors. *Qual Saf Heal Care*. 2004; 13(4):255–259.
78. Gallo de Moraes A, O'Horo JC, Sevilla-Berrios RA, et al. Expanding the presence of primary services at rapid response team activations. *Qual Manag Health Care*. 2018; 27(1):50–55. [PubMed: 29280908]
79. Bagshaw SM, Mondor EE, Scouten C, et al. A survey of nurses' beliefs about the medical emergency team system in a canadian tertiary hospital. *Am J Crit Care*. 2010; 19(1):74–83. [PubMed: 19542059]
80. Butcher BW, Quist CE, Harrison JD, Ranji SR. The effect of a rapid response team on resident perceptions of education and autonomy. *J Hosp Med*. 2015; 10(1):8–12. [PubMed: 25603788]
81. Astroth KS, Woith WM, Jenkins SH, Hesson-McInnis MS. A measure of facilitators and barriers to rapid response team activation. *Appl Nurs Res*. 2017; 33:175–179. [PubMed: 28096014]
82. Lobos AT, Costello J, Gilleland J, Gaiteiro R, Kotsakis A. An implementation strategy for a multicenter pediatric rapid response system in Ontario. *Jt Comm J Qual Patient Saf*. 2010; 36(6):271–280. [PubMed: 20564889]
83. Braaten JS, DeGunst G, Bilys K. Rapidly increasing rapid response team activation rates. *Jt Comm J Qual Patient Saf*. 2015; 41(9):421–427. [PubMed: 26289237]
84. Jackson S, Penprase B, Grobbel C. Factors influencing registered nurses' decision to activate an adult rapid response team in a community hospital. *Dimens Crit Care Nurs*. 2016; 35(2):99–107. [PubMed: 26836604]
85. Radeschi G, Urso F, Campagna S, et al. Factors affecting attitudes and barriers to a medical emergency team among nurses and medical doctors: A multi-centre survey. *Resuscitation*. 2015; 88:92–98. [PubMed: 25578292]
86. Rihari-Thomas J, DiGiacomo M, Phillips J, Newton P, Davidson PM. Clinician perspectives of barriers to effective implementation of a rapid response system in an academic health centre: A focus group study. *Int J Heal Policy Manag*. 2017; 6(8):447–456.
87. Litvak E, Pronovost P. Rethinking rapid response teams. *JAMA*. 2010; 304(12):1375–1376. [PubMed: 20858881]
88. Walston J, Cabrera D, Bellew S, Olive M, Lohse C, Bellolio F. Vital signs predict rapid-response team activation within twelve hours of emergency department admission. *West J Emerg Med*. 2016; 17(3):324–330. [PubMed: 27330665]
89. Gerry S, Birks J, Bonnici T, Watkinson PJ, Kirtley S, Collins GS. Early warning scores for detecting deterioration in adult hospital patients: a systematic review protocol. *BMJ Open*. 2017; 7(12):e019268.
90. Stites M, Surprise J, McNiel J, Northrop D, de Ruyter M. Continuous capnography reduces the incidence of opioid-induced respiratory rescue by hospital rapid resuscitation team. *J Patient Saf*. 2017; 0(0):1–5.
91. Churpek MM, Yuen TC, Winslow C, Meltzer DO, Kattan MW, Edelson DP. Multicenter comparison of machine learning methods and conventional regression for predicting clinical deterioration on the wards. *Crit Care Med*. 2016; 44(2):368–374. [PubMed: 26771782]
92. Goel VV, Poole SF, Longhurst CA, et al. Safety analysis of proposed data-driven physiologic alarm parameters for hospitalized children. *J Hosp Med*. 2016; 11(12):817–823. [PubMed: 27411896]
93. Alonso NP, Pardo Rios M, Juguera Rodriguez L, et al. Randomised clinical simulation designed to evaluate the effect of telemedicine using Google Glass on cardiopulmonary resuscitation (CPR). *Emerg Med J*. 2017; 34(11):734–738. [PubMed: 28768700]
94. Bergmeir C, Bilgrami I, Bain C, Webb GI, Orosz J, Pilcher D. Designing a more efficient, effective and safe Medical Emergency Team (MET) service using data analysis. In: Scherag A, editor *PLoS One*. Vol. 12. 2017. e0188688
95. Pappas PA, Tirelli L, Shaffer J, Gettings S. Projecting critical care beyond the ICU: An analysis of tele-ICU support for rapid response teams. *Telemed e-Health*. 2016; 22(6):529–533.
96. Bogenstätter Y, Tschann F, Semmer NK, Spychiger M, Breuer M, Marsch S. How accurate is information transmitted to medical professionals joining a medical emergency? A simulator study. *Hum Factors*. 2009; 51(2):115–125. [PubMed: 19653477]

97. Hunziker S, Pagani S, Fasler K, Tschan F, Semmer NK, Marsch S. Impact of a stress coping strategy on perceived stress levels and performance during a simulated cardiopulmonary resuscitation: a randomized controlled trial. *BMC Emerg Med.* 2013; 13:8. [PubMed: 23607331]
98. Wehbe-Janek H, Pliego J, Sheather S, Villamaria F. System-based interprofessional simulation-based training program increases awareness and use of rapid response teams. *Jt Comm J Qual Patient Saf.* 2014; 40(6):279–287. [PubMed: 25016676]

Figure 1.

Table 1

Future directions for Rapid Response Systems

Category	Examples
Detection arm	Improving activation criteria using EHR data and complex analytics
	Closer patient monitoring through technology (e.g., wearable devices)
	Finding the right balance between sensitivity and alarm fatigue
Response arm	Determining the optimal leader and team composition
	Developing standardized diagnostic and treatment algorithms
	Computerized clinical decision support tools
Outcomes	Identifying the core outcomes to measure impact
	Local and national reporting of metrics
Quality assurance	Merging technology and simulation training
	Communication training and standardized hand-offs